The magazine of aerospace technologies / NOV. 1959

space aeronautics

formerly Aviation Age

special report:

production & materials engineering

a conover-mast publication

Rec 11/8/59 MR

THE PROBLEM: how to control aviation fuel during high-impact conditions so that instantaneous vaporized combustion can be prevented.

THE GOODYEAR ANSWER: Safety Cell, a high-strength, low-weight fuel tank made of super-tough rubberized fabric. Under exhaustive testing, in cooperation with the Federal Aviation Agency, these tanks have successfully withstood impacts exceeding 30 G's—maximum level of human tolerance. This means that the danger of vaporized combustion at impact is substantially reduced. Thus, the opportunity for survival is materially increased. A number of these tanks are already in use.

THE SIGNIFICANCE: personnel and property protection against full vapor combustion far beyond any type previously obtainable.

More information on Safety Cell, the revolutionary new fuel cell, is yours for the asking. Simply write Goodyear, Aviation Products Division, Akron 16, Ohio.

AVIATION PRODUCTS BY

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*Safety Cell—T. M. The Goodyear Tire & Rubber Company, Akron, Ohio

MORE AIRCRAFT LAND ON GOODYEAR TIRES, WHEELS AND BRAKES THAN ON ANY OTHER KIND

space aeronautics

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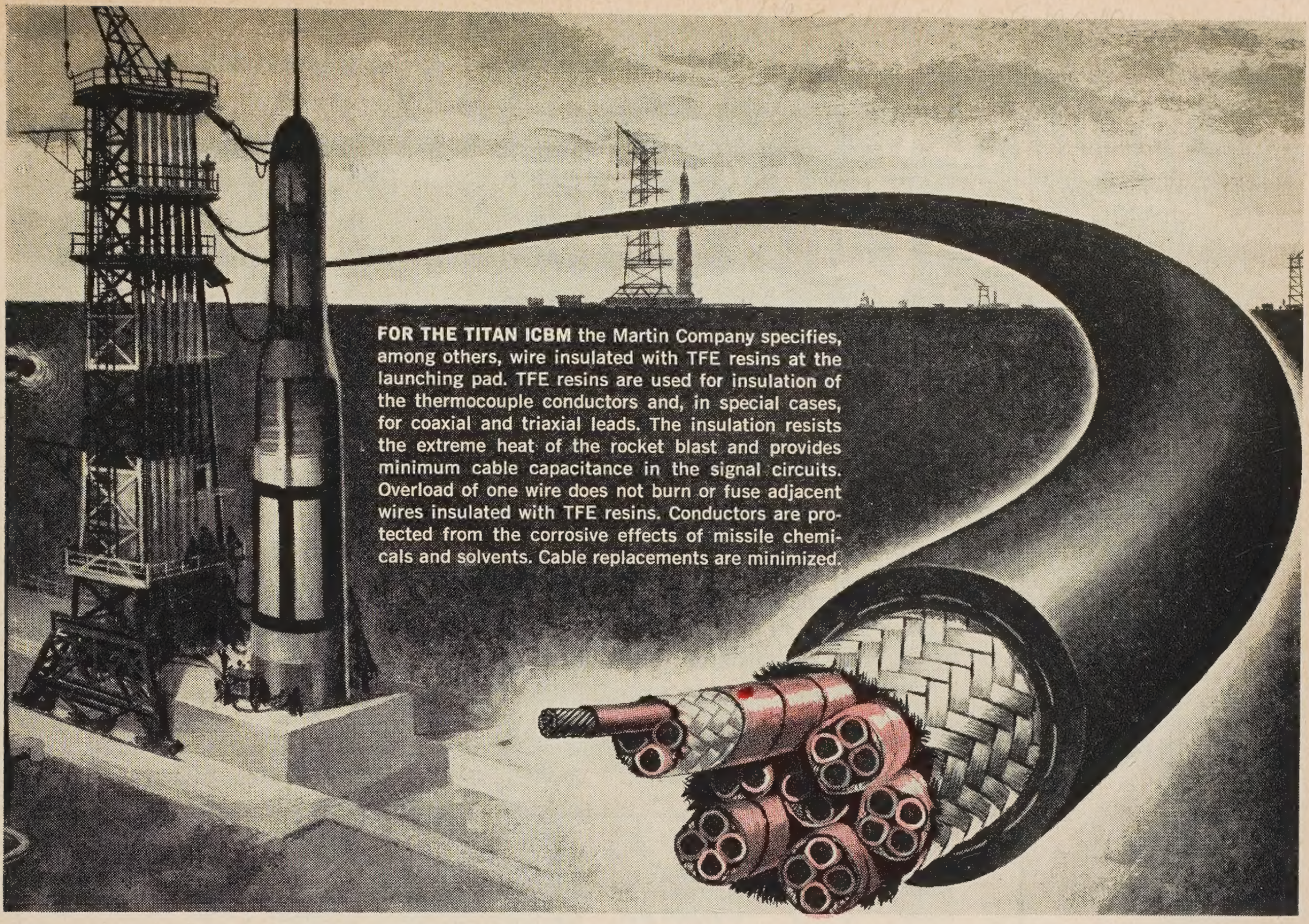
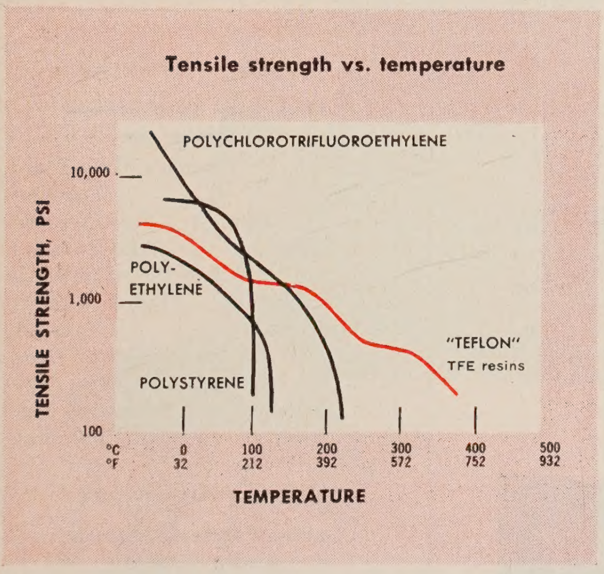


TFE resins outperform all other organic insulations in resistance to temperatures and heat aging



You can depend on TFE-fluorocarbon resins, because they retain useful mechanical and electrical properties far beyond their continuous service rating of 260°C. In fact, these resins maintain appreciable mechanical strength even past their 327°C. (621°F.) gel point, as the curve at left shows. When you use wire and cable insulated with TFE resins you get an extra factor of safety against high ambient temperatures and conductor overheating due to current overloads. The insulation will not melt, char, burn, embrittle or cut through.

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Call your supplier of wire and cable insulated with TFE resins today. He's listed in the Yellow Pages under "Plastics—Du Pont." For additional technical data write to: E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Dept., Room T-611, Du Pont Bldg., Wilmington 98, Delaware.

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BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

Write in No. 2 on Reader Service Card at start of Product Preview Section

cover story

Gigantic machine tools, an advanced honeycomb structure, and the molecular structure of a combined material were brought together on this month's cover by artist George Meyerriecks to describe the scope of SPACE/AERONAUTICS special report on Production and Materials Engineering. Beginning on page 39, this report surveys the state of the art and the outlook for the future in the fields of production and materials. It includes detailed reviews of materials working equipment and methods, evaluations of new metallic and non-metallic materials, and special articles devoted to the problems of electronic materials and production.

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November 1959

space/aeronautics

volume 32 number 5

Technical Management

Special Report: Production & Materials Engineering

Aerospace Engineering

Aerospace Electronics

Features

The editorial content of Space/Aeronautics is regularly examined for readability by Robert Gunning Assoc., counselors in clear writing. These consultants meet periodically with the editors and discuss comparative readability ratings.

in this issue

Here's a quick rundown of the technical information offered in the articles in this issue. You can also use these article abstracts to build up your own permanent record for reference in the future—just clip them, paste them up on standard three-by-five cards, and file them.

Special Report:
Production & Materials Engineering

Astia code: 14-1, -2, -6, -8, -9; 16-2, -4, -5, -6, -7, 26-1, -5
Your code:

"Exotic" materials trigger production "revolution"

Trends in new materials for aerospace vehicles and their effect on the industry's production equipment and processes. Expected changes in joining, machining, and forming methods are discussed.

by Irwin Stambler, Associate Editor & Project Leader

space/aeronautics 32/5 (Nov. '59) p. 39

Special Report:
Production & Materials Engineering

Astia code: 14-8; 26-1
Your code:

New resins lead structural plastics development

Phenyl-silane copolymers, epoxy-novolacs, and peracetic-acid-type diepoxides are reviewed to show state of the art in resin development. Details are given on these materials' structures, application, and fabricability.

by E. J. Zeilberger & J. H. Lieb, North American Aviation

space/aeronautics 32/5 (Nov. '59) p. 60

Special Report:
Production & Materials Engineering

Astia code: 17-4, -5, -6; 26-5
Your code:

Machine tools: From new techniques to new designs

Review of state of the art in machine tools and machine tool cutters, including data on the use of current cutters to machine AM 350 alloy. Forecast of cutting-type machine tool developments over the next decade.

space/aeronautics 32/5 (Nov. '59) p. 44

Special Report:
Production & Materials Engineering

Astia code: 26-1
Your code:

Bonding and welding: ideal for new aerospace materials

Two-part review of inert-gas-shielded-arc welding processes and the fabrication of structural sandwich assemblies. Details are given on materials, production rates and limitations, and the potential of processes and techniques in use or under development.

space/aeronautics 32/5 (Nov. '59) p. 63

Special Report:
Production & Materials Engineering

Astia code: 17-4, -5, -6; 25-6
Your code:

High Temperature chipless methods for machining metals

Review of status of chipless machining techniques. Covers chemical milling, electrolytic, electric-discharge, electron-beam, ultrasonic, and plasma-jet machining, and material displacement. Gives advantages and limitations of each process and types of materials it can handle.

by Alfred G. Jones, North American Aviation

space/aeronautics 32/5 (Nov. '59) p. 48

Special Report:
Production & Materials Engineering

Astia code:
Your code:

New materials pose problems for mechanical joining

Review of the state of the art in the riveting and bolting of aerospace structure. The trend to higher strength fasteners is discussed and the need for new methods of hole preparation in high strength, high temperature metals.

by Irwin Stambler, Associate Editor

space/aeronautics 32/5 (Nov. '59) p. 73

Special Report:
Production & Materials Engineering

Astia code: 17-4, -5; 26-1
Your code:

Production know-how gaining on superalloys and refractory metals

Report on status of metals for service over 1000-deg F regarding properties and producibility. Curves of mechanical properties of commercially available and experimental alloys. State of the art in machining, forming, and otherwise working these metals is reviewed.

by R. H. Sparling, Convair

space/aeronautics 32/5 (Nov. '59) p. 54

Special Report:
Production & Materials Engineering

Astia code: 26-1
Your code:

New techniques, greater precision for forming processes

Survey of state of the art in power spinning, forging, extruding, sheet rolling, and high energy rate forming. Examples are given of the latest developments in these areas, including details on explosive forming and high energy rate machine tools.

space/aeronautics 32/5 (Nov. '59) p. 85

To make filing easier, each abstract is coded according to the Astia Distribution Guide. Copies of this guide are available from Armed Services Technical Information Agency, Arlington Hall Sta., Arlington 12, Va. There is also room on the abstracts for you to insert your own key if you use a special coding system.

Special Report:
Production & Materials Engineering

Astia code: 26-1
Your code:

Numerical control comes into its own

Description of semi-automatic programing of N-156F nacelle frame production as example of machining of entire N-156F fuselage by numerical control. Typical equations, control lines, and shapes are shown. Advantages of numerical control for advanced production are explained.

by Arthur F. Eskelin, Northrop

space/aeronautics 32/5 (Nov. '59) p. 97

Aerospace Engineering
Systems, Structures, Components

Astia code: 27-2
Your code:

Thor ramjet develops 100,000 hp (Design Progress)

First details of Thor BT-1 ramjet engine showing main interior components, structures, fuel system, and gas flow. Engine is early model of Thor now in production for Bloodhound surface-to-air guided missile in service with RAF and ordered by Swedish Air Force. Develops more than 100,000 hp at Mach 3.

by Randolph Hawthorne, Editor

space/aeronautics 32/5 (Nov. '59) p. 114

Aerospace Engineering
Accessory Systems

Astia code: 24-1, -2
Your code:

How to select aerial cameras

Discussion of basic parameters affecting the performance of aerial cameras and explanation of three nomographs that largely eliminate the computations involved in camera selection. The nomographs give exposure time, target definition, and a series of operational factors.

by Samuel Bousky, Chicago Aerial Industries

space/aeronautics 32/5 (Nov. '59) p. 117

Aerospace Engineering
Accessory Components, Propulsion, Materials

Astia code: 10-5; 27-3
Your code:

Choosing filter media for liquid propellants

Review of factors that influence choice of filter materials for routine and special fluid-system applications. Covers metallic, organic, and inorganic materials. Analyzes best use of sintered-bronze, sintered-stainless, and wire-woven elements. Gives porosity rating ranges and temperature capabilities.

by Gerald J. Harman, Harman Equipment

space/aeronautics 32/5 (Nov. '59) p. 135

Aerospace Engineering
Systems Engineering

Astia code: 1-2, -3; 19-3
Your code:

Firebee design keeps up with fighter capabilities

Design study of Ryan Q2-C Firebee target drone. Changing from passive augmentation of earlier models to active augmentation is discussed. Design changes from earlier models are detailed. Three-views and sectional drawings are shown.

by Irwin Stambler, Associate Editor

space/aeronautics 32/5 (Nov. '59) p. 143

Special Report:
Production & Materials Engineering—Electronics

Astia code: 8-2, -3
Your code:

What makes a good thermoelectric material?

Study of thermoelectric materials centers around understanding and control of electric and thermal conductivities and thermoelectric power. These factors and their interrelationships are analyzed. Two thermoelectric material research programs at Servomechanisms are discussed.

by Gordon Steele, Servomechanisms

space/aeronautics 32/5 (Nov. '59) p. 164

Special Report:
Production & Materials Engineering—Electronics

Astia code: 8-2
Your code:

Diffusion promises more efficient semiconductor production

Diffusion may answer many of the problems in semiconductor manufacture. Performance of diffused devices and inherent design flexibility of the process make mechanized production less of a gamble than with previous semiconductor types. Production steps for diffused transistors and diodes are outlined.

by James Holahan, Electronics Editor

space/aeronautics 32/5 (Nov. '59) p. 169

Special Report:
Production & Materials Engineering—Electronics

Astia code: 8-2
Your code:

Metal-oxide additives for high-K capacitor ceramics

Analysis of formulation of high-K capacitor bodies. Some typical high-K materials are detailed. The effects of adding varying amounts of metallic oxides are plotted and techniques for achieving high-temperature stability without sacrificing dielectric constant are outlined.

by F. N. Bradley, Boeing Airplane

space/aeronautics 32/5 (Nov. '59) p. 181

continued on page 13

JET ENGINE SUPPRESSOR

WITHSTANDS SUPERSONIC SHOCK

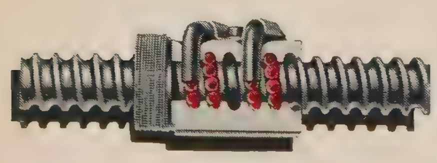
BUTTRESSED BY THE Saginaw b/b Screw

Suppressor in use behind an Air Force F-86 H "Sabrejet"

Muting the ear-shattering roar of a jet engine on pre-flight "run-ups" is the job of Koppers Company, Inc.'s new Portable Run-Up Suppressor. And four Saginaw Ball Bearing Screws—flanking the body of the Suppressor—help hold it rock-steady against the full force of the jet engine's supersonic blast!

These Saginaw b/b Screws enable the Suppressor to be hand-raised or lowered into position faster and with far less effort than by any other manual means. The reason? The Saginaw b/b Screw converts *rotary* motion into *linear* motion with over 90% *efficiency!* And the dependable Saginaw Screw also played a significant part in keeping the Suppressor both light in weight and portable in design.

Whether you manufacture miniature electronic controls or giant production equipment, the Saginaw b/b Screw may be able to give *your* products that valuable **S**ales **A**ppeal you're looking for. To discover all the benefits it can bring you, write or telephone Saginaw Steering Gear Division, General Motors Corporation, Saginaw, Michigan—*world's largest producers of b/b screws and splines.*



Give your products NEW SALES APPEAL... switch to the Saginaw ball/bearing Screw

WORLD'S MOST EFFICIENT ACTUATION DEVICE

continued from page 11

in this issue

Aerospace Electronics

Astia code: 8-2
Your code:

Designing transistor circuits with statistical techniques

Detailed digest of parts of "Transistor Application Manual" prepared by Arinc Research. Statistical methods are described for applying transistors in military electronic equipment. Probability distributions and statistical techniques for determining the effects of part tolerances on circuit output are derived.

by James R. McDermott

space/aeronautics 32/5 (Nov. '59) p. 191

Aerospace Electronics

Astia code: 6-3
Your code:

Physics and applications of photon IR detectors

Concise review of the fundamental physics of the most widely used infrared detectors—the photoemissive, photoconductive, and photovoltaic types. Latest advances in IR masers are covered. Diagrams of electronic energy structure of semi-conductors, impurity energy levels in the forbidden gap, and the PEM effect.

by Marvin M. Antonoff, General Electric

space/aeronautics 32/5 (Nov. '59) p. 205

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2 Fill in your name, title, company, and address and check the type of project your work applies to.

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coming next month

THERE IS little question any more that the Russians are clearly ahead of us in space developments. The question now is, Why did we fall behind and how can we pull even? On the basis of exclusive information on the technical and political problems involved in our space effort, SPACE/AERONAUTICS will try to point the way to an answer by analyzing both our present shortcomings and the requirements for greater success in the future.

HOW MOBILE can GSE get? Pretty mobile, if the support equipment for one of our latest tactical ballistic missiles is any indication. This advanced GSE design will be the subject of a detailed engineering analysis.

PERHAPS in no other field are futuristic designs as dazzling as in propulsion. Only these bold new concepts are all on paper, of course, and that's where they'll remain for some time. The really important question for our propulsion progress is, What can we do with the hardware we have? An answer to this question will be given by Contributing Technical Editor Kurt Stehling.

coming soon

ANOTHER SPECIAL REPORT — on Undersea Weapon Systems. As part of this project, SPACE/AERONAUTICS will present staff-written state-of-the-art surveys on the problems of detection, navigation, guidance, powerplants, structures, and materials as they affect the latest field to be opened up to the aerospace industry. Among several additional features, an outstanding one will be a thorough review of the properties and peculiarities of the physical environment of undersea operations.

keeping in touch

Why write for technical magazines?

SOME COMPANIES have seen that it is a good thing for all concerned if their technical people get articles published in recognized technical journals. Two big ones that come to mind are Convair and General Electric.

Convair, particularly, is an example of enlightened interest in this matter. The San Diego aerospace firm has set up a writing award plan to encourage its engineers to write for recognized scientific and technical journals. General Electric, although it has decentralized its activities in getting GE personnel to write articles, nevertheless makes a continuous effort in that direction.

It is a surprising fact that, with all the tons of technical data ground out each year by the industry in engineering developments and research reports, relatively little of it gets to people who could use it. Either most technical people don't know particular data exists, or they can't readily lay hands on it, or, simply because the data isn't "packaged" so they can absorb it readily, they don't read it.

Yet all engineers hunger for ideas they can use in their jobs. The corollary of this is they have ideas that their colleagues, in or out of their specialties, also hunger for in their work. We have seen this in the thousands of requests we get from readers for technical information.

Companies and R&D institutions and centers have a special interest in this situation. Time and again we hear the complaint from a company PR man that "no one knows we are in this field." How many know, for instance, that Ryan Aeronautical activities now are about 50 per cent in electronics? Or that it is a specialist in Doppler?

With the diversifying that has been going on in recent years, such matters become of top importance not only to the company directly concerned, but also to other firms who have special problems they want handled by subcontractors.

Then there is the matter of attracting badly needed personnel. A good technical article will help a lot in getting them.

Of course, one way to get a "story" of new company activities across is to advertise. But, much as we love our advertisers, we must admit an ad isn't necessarily the only or even the best way to do the job. An article that shows the depth of penetration into a special field, and the competence of the personnel engaged in it, goes a long way toward arousing in a technical reader the feeling, "Now there's an outfit I'd like to join." This creates the proper climate for an ad in the proper journal.

By getting published, the writer increases prestige for himself and for his organization. SPACE/AERONAUTICS, on the other hand, has the selfish interest of getting topnotch technical articles for its readers. Unless we continue to attract our high quality readership, our advertisers will stay away from us in droves.

Those managements in industry who haven't thought about technical magazine writing incentive plans for their engineers and scientists might weigh the advantages. At the very least they could give their PRs some encouragement to dig out the talent. Write our Editor for his Editorial Requirements instruction sheets, which give information on what is wanted, how it is wanted, style, who our readers are, and what our editorial concept is.

Britain's Jodrell Bank radio telescope

Kurt Stehling, SPACE/AERONAUTICS' Propulsion & Astronautics Editor, sent us some details about the great Jodrell Bank radio telescope, which he visited while in England. It has been in constant demand ever since the first Sputnik bleeped out in space. The day Kurt walked in, they were tracking the latest Discoverer (August shot). A Space Technology Labs crew works with the British on coordination of Able and other U.S. space launchings, as well as the USSR's.

The steerable telescope is a full paraboloid. It is 250 ft in diameter and has its focus in the plane of the aperture. Its surface is a solid membrane of welded steel sheets. Kurt says this is better than copper mesh (the material first planned) since all losses due to transmission on short wavelengths—less than 21 cm—are avoided.

The parabolic surface can be kept to an accuracy of better than ±1 in., Kurt says. This gives a beamwidth of six degrees between half-power points at one meter wavelength. The 2100-ton structure moves in azimuth, declination, and right ascension with a maximum automatic scan rate of 20 deg/min. Relatively small electric motors powers it, Kurt found.

Many new radio sources have been detected and measured in the 21-cm region, he reported.

William G. Maass

Publisher

WHEN IT COMES TO SHIELDED WIRE

SLIDE on the ferrule

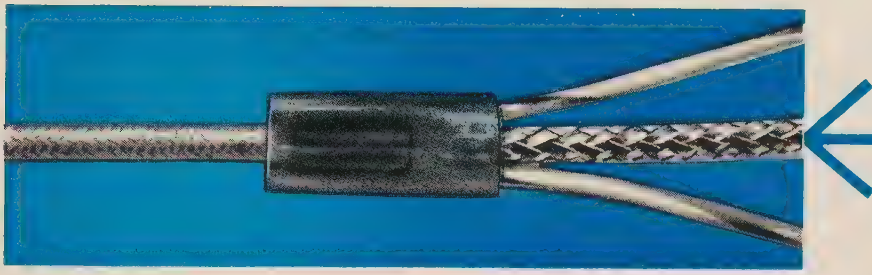
SLIP in the ground taps

CRIMP the three together

SNAP on the insulation

PRESTO!

the best insulated ferrule you can buy



How's that for speed! And the post-insulation of the Termashield Shielded Wire Ferrule is easily and quickly accomplished . . . you eliminate close tolerance cable stripping required by other techniques . . . you eliminate blind probing of taps into other type ferrules . . . you eliminate solder and burnt cable . . . you eliminate lost time . . . you eliminate doubt.

For positive attachment, top reliability, unbeatable speed and tangible economy, get A-MP Post-Insulated Termashield Shielded Wire Ferrules.

Write for more information.

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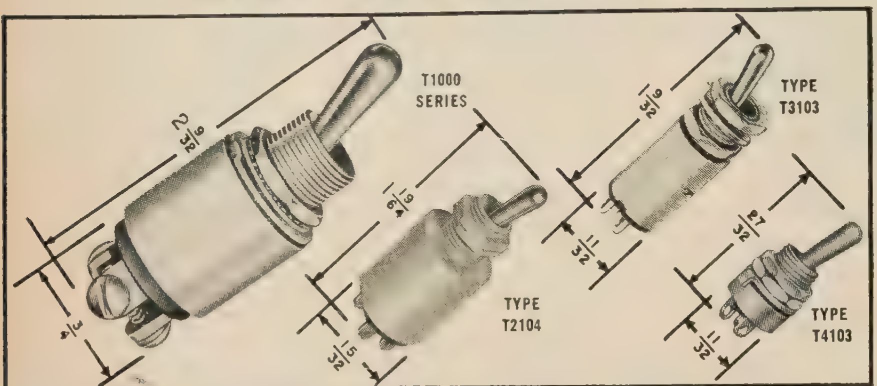
HETHERINGTON

SWITCHES • INDICATOR LIGHTS • SPECIAL ASSEMBLIES

ENGINEERING NEWS

Say "WHEN" to Toggle SWITCH MINIATURIZATION



Few basic electrical components have been successfully miniaturized with such telling effect as the toggle switch. Hetherington has developed space- and weight-saving cylindrical types with ratings, dimensions, and performance tailored to the critical requirements of airborne and industrial electrical systems. And, thanks to Hetherington's positive cam-roller snap action, even the smallest types carry ratings far greater than their sizes would indicate.

Recent Hetherington developments such as the sub-miniature Type T4103 shown above approach the point where further miniaturization would seem to present more difficulties in mounting than in obtaining adequate switch performance. Although not quite ready for production, field tests of the T4103 have shown great promise for drastically cutting weight while assuring better performance in aviation's toughest jobs.

Write in No. 100 on Reader Service Card

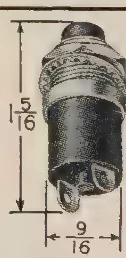
"BILLBOARD" LIGHTS
Make Crowded Panels More Meaningful

Too often the significance of tiny conventional indicator lights is hard to determine at first glance—especially if many are used on one panel. With Hetherington Placard Lights, vital control information can be read directly in terms of symbols, digits, abbreviations, words, or entire phrases engraved on plastic lenses. Two miniature AN3140 lamps boldly illuminate the lettering, thus avoiding delay or errors of interpretation.

In spite of their large (1-3/8" x 9/16") lenses, over 40 Placard Lights fit comfortably in a 9 x 5" area thus simplifying many annunciator-type panels where lights are closely grouped. For details, write for Data Sheet L-3.

Write in No. 101 on Reader Service Card

8 AMP U. L. RATING
... ½ amp Size and Price



Here's just the push-button switch to dress-up and improve that instrument, appliance or other "black box" now on the drawing table—and with attractive cost and space advantages in the bargain.

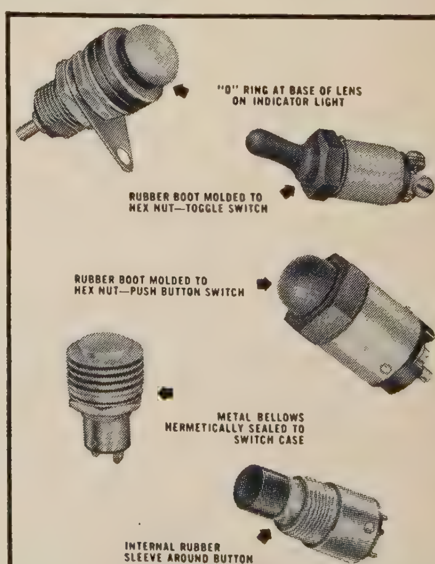
For the performance of these B-Series Switches comes mighty close to that of Hetherington's aviation-quality switches in terms of positive "feel," fast and audible snap-action. Normally-open or closed SP-ST types with 8-amp U.L. Approved ratings available with lugs or 6" leads. Send for Data Sheet S-4.

Write in No. 102 on Reader Service Card

SWITCH PROTECTION "TAILORED"

to humidity
...moisture
...spray
...immersion

Although the mechanism of every Hetherington push-button and toggle switch is protected by the case against dust and moisture, some special requirements call for additional "climate-proofing." Where the perfect hermetic seal of a metal bellows is not needed, "O" rings, sleeves or boots of lightweight silicone rubber offer inexpensive solutions for most applications as shown by the typical types at right.



HETHERINGTON INC. DELMAR DRIVE, FOLCROFT, PA. • 139 Illinois St., El Segundo, Calif.

standard switches for the most specialized requirements

"A Controls Company of America Subsidiary"

editorial

Pollyanna policy

WE HOPE to eat these words, but analysis of the results of the recent Khrushchev "peace" invasion indicates we've bought a pig in a poke.

The President himself unwittingly confirmed this concluson. Asked whether he felt the conditions he had set for summit talks on Berlin had been met by the Soviet chief, Mr. Eisenhower said:

"I would say, for myself, this: The conditions I have set so far, so far as I am concerned, I mean the conversations have, so far as I am personally concerned, removed many of the objections I have heretofore held; but again this is a matter of negotiation and consultation with our allies. And, as I say, the progress that has been made is, I can say that we have to consider, as long as we are going to negotiate, that there is progress because we are not on an impasse."

We orbited several times about this statement, examining it on all sides.

The only good we found is that—temporarily—the Berlin crisis is postponed. But clearly the President was a bit unsure of what he was saying. He just was not certain of the assurance he had got from Khrushchev. In fact, he had nothing tangible to show.

The world's most powerful and highly trained falsifier insisted that the "assurance" given the President should be verbal, not in the written communique on their meeting. The Berlin talks, it was thus agreed, "should not be prolonged indefinitely, but there could be no fixed time limit on them." This can mean anything Khrushchev wants it to mean.

WITH THIS IRONCLAD guarantee inscribed in the air of Camp David by the gracious Mr. Khrushchev, our defense program took another nosedive. More cutbacks, cancellations, and cheese paring took place and will take place on the strength of the new era of "good will."

So much for the political background. Now take a look at the state of our technological "race" with the Soviets in space flight and missiles.

Dr. Wernher von Braun—after the first Red moon shot—said not only are we not spending enough on space flight, but at the present rate of progress it will take us three years to catch up if the Reds stand still. (Obviously they are not.)

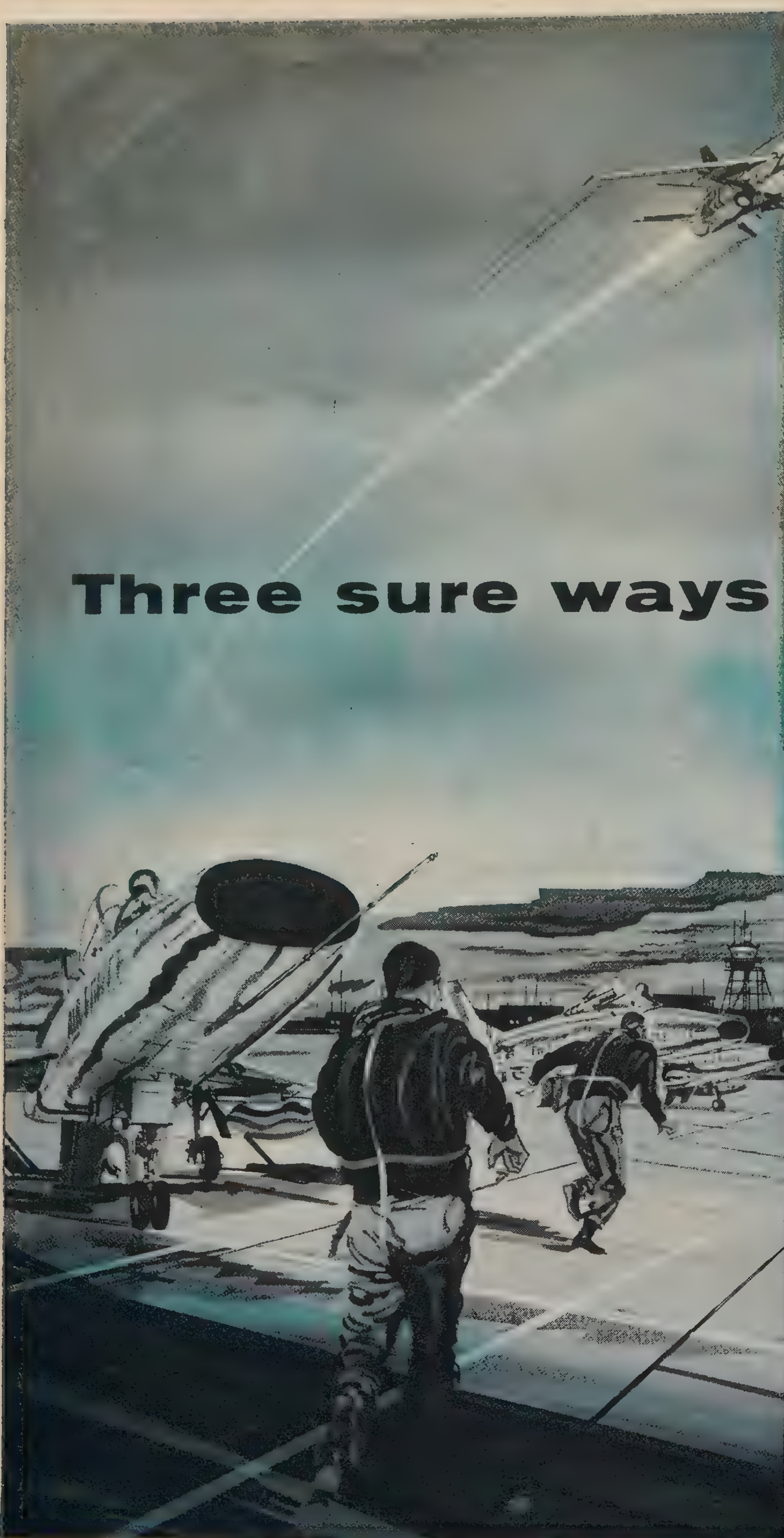
Dr. Arthur R. Kantrowitz, director of Avco's Research Laboratories, called on the Administration to take "the space competition more seriously instead of disavowing that we are in competition."

Dr. Charles S. Draper, head of MIT's Department of Aeronautics & Astronautics, believes we are "running second" to the Soviets because of what he called official "hassles."

Meanwhile the crucial missile gap yawns wider. According to present goals, by 1963 the U.S. will have the 130 ICBMs as against a Soviet "capability" of 1500.

Such is the measure of the President's pollyanna policy.

Randolph Hawthorne, Editor



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washington briefing

by A. N. Wecksler, Washington Bureau Chief

AF pushes "mixed weapon concept"

WITH MISSILES entrenched in the world's arsenal of war, the question logically arises as to the position of manned weapons in both offense and defense.

The Air Force answer is the "mixed weapons concept," which simply means that AF strategy employs both manned and unmanned weapons. The mix may change. The trend is toward more missiles—cheaper, expendable, and more versatile. In manned aircraft, the trend is toward fewer weapons—bigger, faster, longer range, and capable of performing different kinds of missions.

In both manned and unmanned weapons, the cost of development and production is so great that all the services are being forced into hard choices between weapons which they feel they need more urgently.

This need to choose dictated the Air Force decision to go ahead with the development of a Mach 3 B-70 bomber—and to drop the F-108 fighter.

In making the choice between the B-70 and the F-108, the Air Force revealed much of its thinking behind the mixed weapons concept.

A great point has been made in public discussion that the manned weapon provides a period of decision—that bombers can be dispatched on a mission at the instant when there is an alarm, and still be recalled if the alarm turns out to be in error.

This obviously has public appeal, but from a military point of view, there are two characteristics of a manned aircraft which supersede in importance even these qualities:

- The manned weapon is immensely more accurate.
- The manned weapon can deliver much greater force.

It is true that the missile can destroy a manned weapon while it is on the ground, but once in the air a manned weapon has a good chance of survival to deliver its bomb load.

Here is how the Air Force anticipates using the mixed weapons at its command: Assuming an attack on us with missiles, the immediate retaliation would be with our missiles. The exchange of missile barrages would destroy large areas—and in the destruction, communication facilities would be major targets.

The destruction of communication facilities would disrupt the air defense of both sides. The Air Force position is that communications are the most vulnerable sector of our military position. Missiles with a circular error probability (CEP) of two miles would not be effective in singling out specific targets, but they would knock out a large part of the communications network in the target area.

With communications disabled, the air defense network—both missiles and fighter aircraft—would become less effective. At this point, the manned bomber would be able to pinpoint targets.

While the CEP of ballistics missiles is now measured in miles, the CEP of bombers is measured in feet. Air Force thinking concedes that to go in with manned weapons against targets with intact air defense would result in a high casualty rate.

The preferred tactics would be to keep the bomber strength protected in hardened bases or aloft until the air defenses had been breached.

The Air Force view is that missiles now are limited because of insufficient accuracy, and that manned weapons alone can now make up this deficit.

To the degree that missiles can be developed with more accuracy, they could assume a larger role in our planning.

The Air Force thinking concedes that satellites might be developed that would release a warhead over a target on command from a ground control post. But this kind of sophistication, says the Air Force, is costly day-dreaming—with the cost of a satellite running as high as $50 million, the addition of a big payload would run such a weapon far out of reach.

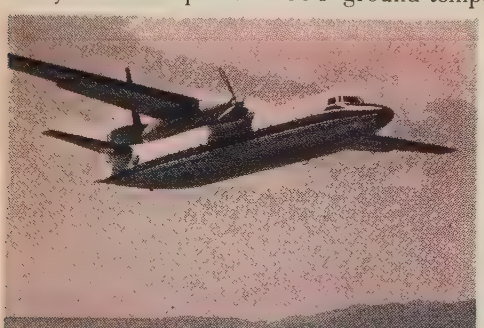
The Air Force's mixed weapon concept is much more practical. When queried whether this concept has the backing of the Department of Defense, an Air Force spokesman pointed out that DOD has little choice. Our present superiority over the Soviets is only derived from manned weapons — they outclass us in missiles, and so our only present safety lies in mixed weapons.

In Any Climate, Flexibility

SILASTIC SILICONE RUBBER Seals Fairchild F-27 Doors at -50 F

Fairchild's new F-27 propjet brings back the days of the versatile, multi-purpose transport. And one of the reasons this plane can fly anywhere, sit overnight on icy Alaskan runways, and carry a "flexible" payload is Silastic®, the Dow Corning silicone rubber.

This sounds like a lot to ascribe to a door seal, but it does play a really important part. The F-27B's for Northern Consolidated Airlines must be ready to roll in spite of —50 F ground temperatures. Their passenger doors



and big cargo doors need Silastic seals because Silastic stays rubbery down to —130 or up to 500 F. With an organic rubber seal, the doors wouldn't open and close at —50. Silastic also resists equatorial weather, and springs back to shape after being compressed under load. So when the door opens to load either passengers or cargo, it will come shut again on a reliable seal that keeps its original properties and holds cabin pressure.

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by Robert M. Loebelson, Associate Editor

Services will always need manned aircraft

ALTHOUGH the Air Force has decided to cancel the F-108 interceptor because of a shortage of funds, there are still many proponents of the manned aircraft. One of these, for obvious reasons, is Raymond H. Rice, vice president of North American Aviation and general manager of the company's Los Angeles Division.

Rice is convinced that the Strategic Air Command will always have a use for manned bombers (like the B-70) to go with its ballistic missiles. He is equally certain that the Air Defense and Tactical Air Commands will find a requirement for fighters of the F-108-type.

To Rice, the manned bomber firing an air-launched ballistic missile is essential to strategic warfare. "The bomber," he says, "can pinpoint a target much better than a ballistic missile and hit it with much greater accuracy. Manned aircraft can observe enemy territory much better than reconnaissance drones or missiles."

Of the manned fighter, Rice believes it has much greater range than any interceptor missile. "A manned interceptor," he declares, "has much greater search capability than any missile and needs much less coordination with ground stations. Even if Sage or the Dew Line were eliminated, a Mach 3 fighter could still operate, although perhaps not quite as effectively."

The NAA official takes issue with *Pravda's* contention that the USAF's cutback on the boron fuel program spells the end of the B-70 program. "In the first place," he declares, "the research program on boron fuels is continuing. Furthermore, the B-70 is a fine weapon system that will go all the way to the target at Mach 3 speeds on its conventional turbojet engines. The boron was only an item to improve the airplane's range."

Rice insists he doesn't want to deprecate the importance of guided missiles in future aerospace operations. "But," he points out, "the manned aircraft flying at Mach 3 will be a vast improvement over present bombers—it will shorten our reaction time, add to our mission capability, and keep crews airborne for shorter periods. It will also be a much more difficult vehicle for the enemy to intercept."

RAYMOND H. RICE, North American Aviation, Inc., vice president and general manager, Los Angeles Div.

The NAA v-p concedes that missiles have come far enough along so that even Mach 3 aircraft can be knocked out by surface-to-air birds. "But that is where tactics will have to come into play. And the pilot of the Mach 3 bomber will be capable of taking better evasive action than a missile."

Rice also makes the point that our respect for Russia's ability to attack or retaliate is increasing and suggests that manned aircraft may provide greater flexibility. "Our greatest concern now," he points out, "is the local or limited war, rather than the all-out conflict. For operations of this type, the manned airplane—which has man's plus in accuracy—may well be a better solution than guided missiles."

Still more cutbacks in the offing as DOD works on '61 budget

MONEY PROBLEMS continue to plague the Defense Department's planners as budget time for fiscal '61 nears. Despite all the cancellations and cutbacks of the last few months (P6M, F-108, boron fuels, etc.), it looks as though still more reductions will have to be attempted —even though cancellations often result in only small savings because of contract termination costs.

Air Force Secretary James H. Douglas predicts stable USAF expenditures for the next two years, citing reduced spending for fiscal '60, whose level is to be roughly maintained in fiscal '61.

But Lt. Gen. Mark E. Bradley, Jr., AF's Deputy Chief of Staff for Materiel, is warning contractors. While '59 was a rough year for procurement, '60 will be even rougher, and it is difficult to predict what will happen beyond," he says. He points out the AF's $7.9 billion for '60 sounds like a lot but adds, "the big missile program obviously takes sizable proportions of our budget programs. The aircraft program does not get the amount it formerly received."

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NOT ENOUGH money is being allocated to R&D by the military services, the House Space Committee believes. "In view of today's swift scientific pace," the House group declares, R&D money seems clearly inadequate. This is the case, apparently, at all levels of military government."

Highly interesting in a period when budgets are being held down is the Committee's lack of concern about duplication in R&D, especially in the space program. The Committee believes such duplication in the early stages of astronautic development is "by no means unwarranted but . . . in fact essential in many cases."

Army opposes possibility of cuts in TAC strength

DOD'S BELT-TIGHTENING is causing more than the normal wrangling over how much money each service should get. The Army and Air Force, for example, are embroiled in a big hassle over proposed cutbacks in the USAF's Tatical Air Command.

The Air Force, of course, would not like to reduce TAC. But if its fiscal '61 money is to be reduced or kept on a par with '60's, it will be used to keep the Strategic and Air Defense Commands as potent as possible—at TAC's expense, if necessary.

The Army, which depends on TAC's fighter-bombers and Matador and Mace missiles to protect ground troops, is opposing the proposed USAF action. So it may well end up proposing increases in the USAF's budget for TAC. Or it may make good on its past threats to campaign for full control over its own tactical airplanes and missiles.

THE DOD PLANNERS' headaches over the '61 budget are being aggravated by what ARPA Director Roy W. Johnson calls "too much salesmanship" on the part of industrial contractors. Johnson asserts that industry is pushing military systems that "offer rather more to profit than to national security." Pointing out that the DOD budget "must remain close" to '60's $41 billion for the foreseeable future, he urges industry to help government "find the best weapon for operational use."

BuNavWeap to get 40% of all future Navy money, 70% of Navy R&D

THE NEWLY FORMED Bureau of Naval Weapons, headed by Rear Adm. Paul D. Stroop, will get about 40 per cent of all future Navy appropriation. Created by the merger of BuAer and BuOrd, it will also account for about 70 per cent of the Navy's total R&D budget.

BuNavWeap, Navy officials believe will have at least four major advantages over the former two separate bureaus:

- Nearly two-thirds of all the technological work of the Navy will be under one authority.
- Most areas of divided responsibility, which occasionally caused overlapping and duplication in the past, will be eliminated.
- Funding and contracting for major weapon systems will be simplified.
- Field facilities and labs will work together more effectively under a single command.

•

THE NAVY'S AND USAF'S cutbacks in August appeared to kill off the boron-fuel program. However, it now seems the exotic fuel may still find applications in missiles—and perhaps even in aircraft.

Callery Chemical's five-ton Navy plant at Mus-

more on next page

technical management intelligence

kogee, Okla., has been placed on a "hot standby basis." It will undoubtedly be used if boron output on a large scale is revived. Olin Mathieson's eight-ton facility at Lewiston, N. Y., will continue to turn out some boron compounds this year, to be used at least for R&D. There are no plans for use of the USAF-owned Olin Mathieson five-ton plant at Model City, N. Y.

Congress committee wants to shift A-plane from DOD to AEC

THE CONTINUING battle between some Pentagon echelons and some Congressional groups over the aircraft nuclear propulsion (ANP) program grew hotter yet when the Joint Congressional Atomic Energy Committee urged that AEC be given full control of the program. Dr. Herbert F. York, DOD Director of Research & Engineering, countered by creating a high-level Pentagon group to coordinate the program and resolve differences between the Navy and USAF over the type of A-plane to be developed.

York picked Dr. Joseph V. Charyk, Assistant AF Secretary for R&D, to head the committee, which will evaluate progress in the ANP effort as well as attempts to put nuclear engines in existing airframes.

DOD AND AEC now share the responsibility for the ANP program, which is funded at the rate of $150 million a year. About $1 billion has been spent on the project since '46. There's no indication an A-plane will be in the air within the next two or three years.

The Navy is pushing for the development of a slow atomic seaplane, to be used mainly for observation. USAF, which originally wanted a supersonic bomber, now favors the development of a "Camal (*C*ontinuous *a*ir alert, *m*issile launch, *a*nd *l*ow level penetration) aircraft.

THE CONGRESSIONAL Committee's argument for placing the ANP program under AEC is that DOD has no "general operating requirement" for an A-plane and its effort is primarily in R&D. The Committee maintains AEC is fully able to carry the ANP program through the flight feasibility and demonstration stage and then turn it back to DOD.

Under the Committee's proposal, DOD and AEC would continue to cooperate but primary emphasis would be placed on "a groundtest prototype propulsion system and [its] flight testing . . . in an experimental aircraft."

Despite the recommendation, indications are that the ANP program will continue to be funded at the $150 million level for fiscal '61, with DOD and AEC sharing the responsibility for it.

■

WHEN DOD assigned control over space projects to USAF and took ARPA out of the space business, the Army Ballistic Missile Agency came up for grabs. The Von Braun operation at Huntsville, Ala., now is involved primarily with the Martin Pershing IRBM and the 1,500,000-lb thrust Saturn booster. DOD, which obviously intends that AF should operate Saturn, is about to decide how Saturn will be funded in the future.

DOD could let the Army continue to fund Saturn and then turn the booster over to USAF for operational use. This would follow the Jupiter precedent.

Another possibility is to have AF take over the Saturn funding. Still a third is for DOD to turn the Huntsville activity over to NASA, just as NASA Administrator T. Keith Glennan proposed a year ago (with tacit DOD support).

Air Force and NASA are the only two groups to which ABMA can go

ABMA NOW can go only one of two ways—USAF or NASA. The Army, Navy, and ARPA all are out of the booster business—the two services are assigned only payload work on certain satellites, and ARPA in the future is to work on "advanced missile defense, solid propellant research, materials, and such other projects as the Secretary of Defense may decide."

After getting its nose bloodied last year, NASA apparently has no intention of making a pitch to take over the Huntsville operation. On the other hand, it is not known how USAF feels about taking over ABMA.

UNDER THE DOD EDICT giving USAF control of all military space missions, two satellites were given to USAF, one to the Navy, and one to the Army. All were previously assigned to ARPA.

USAF now controls Midas, the ballistic missile early warning satellite, and Samos, the recon vehicle formerly known as Sentry. The Navy takes over the Transit navigation satellite, and

more on page 26

CASE HISTORIES

From New Departure's R&D Laboratories come bearing designs which function outstandingly under damaging effects of *cold* liquid fuels . . . still other N/D bearings perform perfectly in *hot* turbine positions.

N/D Precision Ball Bearings Help Steady The Heart Of The X-15!

In the heart of this piloted space prober, a volatile mixture of liquid fuel is channeled at *10,000 pounds per minute* into rocket thrust, through a unique throttle of the main fuel system. Within this cryogenic system, New Departure corrosion resistant ball bearings *hold* their geometry to within the most exacting specifications . . . giving support to a pair of the metering system's valves, assuring virtually torqueless, millisecond response.

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The X-15 was developed by North American Aviation for the USAF, US Navy and NASA for research in the field of hypersonic flight. The same N/D engineering and manufacturing skills applied to solving *hot* and *cold* ball bearing problems of this first manned advanced research vehicle, are ready for *your* rocket or missile project *right now!* Call or write New Departure Division, General Motors Corporation, Bristol, Connecticut.

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the Army has been given jurisdiction over Notus, the communications satellite family that includes Courier.

TWO CONVAIR DIVISIONS, San Diego and Ft. Worth, are hopeful that USAF's economy decision to eliminate the F-108 Mach 3 interceptor will mean more business for them. High USAF echelons in the AF directorate are still convinced the manned interceptor has a greater potential in some areas than surface-to-air missiles —so Convair-San Diego is hoping for new follow-on orders for the Mach 2 + F-106.

The F-106 has neither the speed (200 mph) nor the range (1000 miles) of the F-108. But it is in production and can do a large part of the job planned for the F-108 at greatly reduced cost, company officials believe.

New B-58 version for interception and tactical missions proposed

CONVAIR-FT. WORTH, on the other hand, is promoting a modified version of the B-58 for interception and tactical missions. It is proposing the use of two 30,000-lb thrust P&WA J58s instead of the four GE J79s on the bomber version.

With the substitute engines, an interceptor B-58 would have the F-108's range and altitude and fly at about Mach 2.5. The modified version of the B-58 will also be suitable for TAC (just as NAA considered the F-108 suitable for TAC as well as ADC).

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CHANCE VOUGHT got a $9.5 million Navy contract to modernize 164 F8U-1 Crusaders, including 17 F8U-1P photoplanes. CV is already modernizing 103 other F8U-1's under a previous contract.

LOCKHEED won a $67.8 million Navy award to build P3V-1 turboprop anti-sub aircraft. The Land-based P3V-1, developed from the Electra, will use four Allison T56s.

MCDONNELL got $137.6 million worth of Navy contracts to produce the F4H all-weather fighter. The F4H was picked over the CV F8U-3 in a competition.

LOCKHEED will continue producing P2V-7 Neptunes under a $19.1 million Navy award covering 26 planes. Output of the patrol plane will now continue into '61.

WESTINGHOUSE will produce the J34-WE-48 turbojet through August '61 under an $11.4 million Navy award. The engine is used on NAA's T2J trainer.

Westinghouse also received a $4.8 million Navy contract covering an engineering development program on turbojets.

ARMY GAVE Western Electric $188.2 million in R&D contracts for the Nike-Zeus anti-missile missile. These funds will also cover studies by Bell Telephone Labs, Douglas Aircraft, and Sperry-Rand.

WE also got a $11 million Army award on the Nike-Hercules.

NAVY'S MISSILEER competition for a subsonic aircraft to launch the Bendix-Grumman Eagle missile is to be decided by about March. Specs for the plane are now going out to interested firms.

DYNA-SOAR may have to be shelved by USAF because of a fund shortage. There is still no decision on the winner between the Boeing and Martin teams.

Orders for Minuteman to be cut back sharply to about 800 missiles

PLANS for the Boeing Minuteman solid ICBM are changing. Orders for more than 2000 Minutemen will be reduced sharply to perhaps about 800. Cost may be brought down to $1 million a copy. And most of the missiles may be deployed on railroad cars and trucks rather than in hardened sites.

The first test vehicle was successfully fired from a silo at Edwards AFB, Calif. The bird is due to become operational early in '63.

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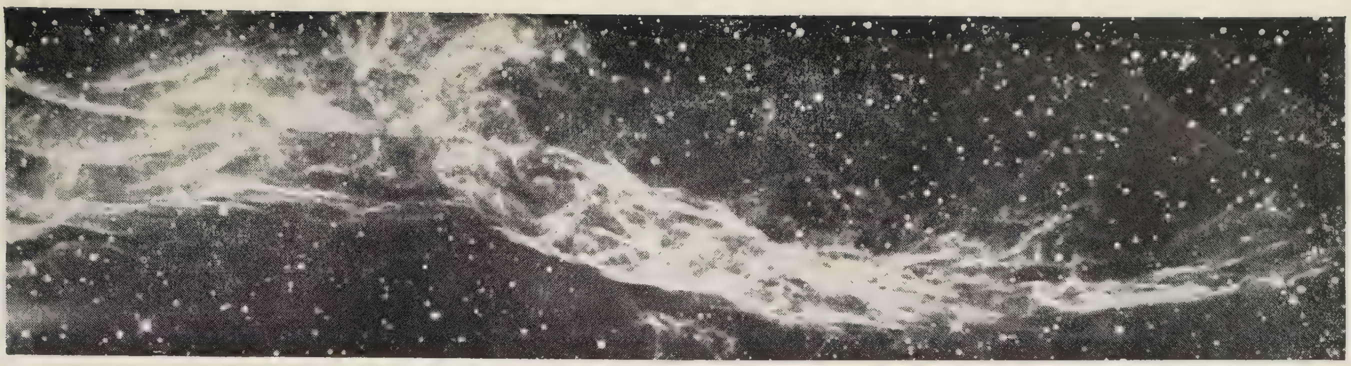
USAF PUT a system development requirement on Slam, a nuclear-ramjet-powered supersonic low altitude missile. DOD has not yet granted the go-ahead on development of Slam for SAC.

Slam is an outgrowth of AEC-Marquardt research on Project Pluto, a nuclear ramjet engine. Feasibility studies on Slam have been completed by Chance Vought, North American, and Convair.



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ALBM fired at satellite rose to 160 miles, covered 1000-mile ground distance

BALLISTIC MISSILE fired from a B-47 last month landed about 1000 miles from its launch point. At launch the B-47 was at about 35,000 ft altitude. The missile was guided close to the Explorer VI paddlewheel satellite's trajectory, some 160 miles above the earth's surface.

Purpose of the test of the air-launched ballistic missile (ALBM) was to prove out missile operation and check guidance accuracy. Telemetry signals and optical and ground radar tracking were used to record the trajectory. The missile released flares at irregular intervals to aid optical tracking. It also released flares as it came closest to the satellite.

THE TWO-STAGE ALBM was about 37 ft long. It was separated from the B-47 for launching before its first stage ignited. As soon as thrust was applied, it pulled up into a near-vertical position to leave the atmosphere.

New satellite spinning at 450 rpm in orbit

EXPLORER VII SATELLITE weighs 91.5 lb. About 70 lb is accounted for by instrumentation and power. It was spun up to about 450 rpm to produce a gyroscopic stabilizing effect while in orbit. Instruments are relaying data back to earth on radiation balance between space and earth, intensity of solar X-rays and ultraviolet rays, intensity of heavy cosmic rays, makeup of the radiation belts, composition of the ionosphere, micrometeorite densities, and erosion of unprotected solar cells.

SOVIET MOON-GO-ROUND satellite is behaving just as predicted, say the Russians. Little design data has been disclosed so far except that the satellite weighs 613 lb and contains an internal pressure control system, a temperature control system to maintain limits of 25 and 30 deg C, two radio transmitters, and solar and chemical batteries.

All the equipment is reported to be operating to the Russians' satisfaction. Power of the radio transmitters was estimated by English scientists to be between five and 20 W.

LUNIK III was diverted by the moon's gravitational force to follow a trajectory back to earth. The Russians say their satellite will orbit around the earth about twice a month for several years —unless, of course, there's a destructive collision with meteorites.

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NUCLEAR RAMJET progressed from the study phase to full-fledged development status. Preliminary research has been carried on for several years under Project Pluto. Now the Air Force has ordered a development engine for possible use in missile and aircraft weapon systems within the next five years. If successful, a nuclear ramjet could become operational in the late sixties.

Drag brakes overcome solid motor burning problems

DRAG BRAKES are used to control the range accuracy of the Sergeant missile. Jet Propulsion Labs hit on this technique as a solution to the problem of variations in the burning time of solid propellant motors.

The drag brakes are in the form of fins, or vanes, that extend and retract from the body of the missile during flight. They are actuated automatically at precisely computed moments to correct the path of the missile on its way to the target. By slowing down the missile and adjusting its trajectory, the brakes can compensate for any variation in burning time.

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CHUTE SOUNDING ROCKET design concept developed by Convair-Pomona has been checked out in a number of full-scale and sub-caliber test firings. The sounding rocket is less than eight feet long. It is fired from a launch tube hanging from three parachutes.

The tube is dropped from a carrier plane at about 20,000 ft altitude. A drag chute slows down the descent while a cluster of three larger stabilization chutes spread out overhead in cloverleaf fashion.

TWENTY SECONDS after its release from the plane, the launch system is fully stabilized. The rocketsonde fires straight up out of the tube, passing between the chutes. In six more seconds, the rocket is moving at Mach 4. Eventually it coasts to an altitude of about 200,000 ft, at which time instrumented nose section is released for a slow parachute descent to earth.

more on next page

On the way down, the instruments take readings of temperature, pressure, humidity, and ozone content of the air every two seconds and transmit the data back to the launching aircraft. This info is then immediately relayed to weather forecasting stations and ballistic message units.

ITS 3A VERSION of the Britannic freighter is lighter than our C-133 but has the same hold capacity, according to Short Brothers & Harland. The 3A differs from the earlier version, announced some months ago, in its larger wing span, provision for more highly developed powerplants, and an increased grossweight.

BLUE STREAK IRBM can be carried aboard the Britannic 3A if the plane's upper rear loading door is removed—a change that reportedly can be made quite quickly. The 3A can also carry Thor, Jupiter, Corporal, Minuteman, Bomarc, Thunderbird, and Bloodhound missiles.

Method sought for rolling 36x96-in. columbium alloy sheet

ROLLING PROCESS for columbium alloy sheet is being developed by Crucible Steel under an AMC Aeronautical Systems Center contract. Crucible is to come up with a method for producing 36x96-in. columbium alloy sheets. The defect-free, highly formable, flat-rolled sheets are to have an ultimate tensile strength of 100,000 psi, a yield strength of 80,000 psi, and a flatness of three per cent. It will take about two years, according to AMC, before the program's final results are in.

The initial phase of the program, says Crucible, will include the evaluation of ingots produced by powder metallurgy furnace sintering and arc casting and establishing the development of methods for casting ingots, and of a control and test system, and of plans for the best rolling technique for sheets with thicknesses of 0.02, 0.04, and 0.063 in. Crucible will also recommend the most promising alloys with high strength properties between 2000 and 2600 deg F. The final alloy selection will be made by WADC's Materials Lab.

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PHOTOS FROM the Explorer VI paddlewheel satellite were taken by a two-pound scanning device developed by Space Technology Labs. The one picture taken from Explorer VI that was released is quite crude and meant nothing to many photo recon veterans with World War II experience. But space scientists say the picture is sufficiently detailed to show cloud formations. Published maps of the photographed area were coded to show 100 per cent cloud cover, broken clouds, and generally cloud-free regions.

The Explorer VI camera contained a mirror that received and focused light and dark impressions for recording in the form of coded lectric impulses. These were converted into radio signals for transmission to the earth, where they were received as a series of dots. The dots formed lines, and these then formed the picture.

New, 300-mile-thick radiation belt discovered by Explorer VI satellite

THIRD RADIATION BELT was discovered by Explorer VI. It contains protons with energies of at least 75,000,000 ev. Scientists believed these protons are produced by atomic disintegration and decay of cosmic rays. According to preliminary data, the belt is some 300 miles thick and is centered around the geomagnetic equator about 1200 miles above the earth.

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AIR-CUSHION cargo ship is being built by Spacetronics, of Washington, D.C. Its hull is made of aluminum extrusions and sheet (supplied by Alcoa and packed with styrofoam to provide buoyancy and strength).

Spacetronics' design has the shape of a tear drop. It is 32 ft long and about 24 ft across at its widest point. The hull is two feet high. A horizontally rotating prop in the bow will deliver a continuous flow of air pressurized to just a few ounces per square inch. This is enough pressure, the company says, to lift the ship about two feet off the surface of the water.

PROPULSION for the air cushion ship will be provided by aft-mounted fans. Speeds up to 50 mph and possibly more are expected. According to Spacetronics, the air cushion will not kick up a thick spray during operation.

TREND IN SERVO component development is toward nuclear-resistant operation—which means high temperature operation too. Norden-Ketay recently developed a number of 300-deg C units for Systems Research Labs. of Dayton, Ohio.

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Idea sessions

on going places

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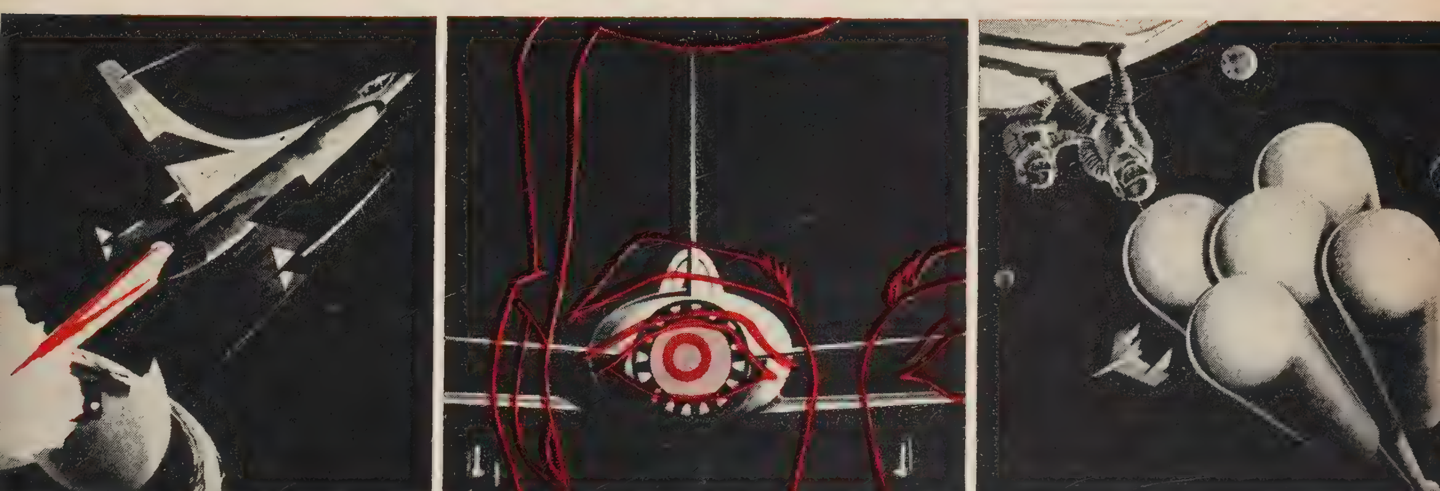
often put

the future as near as the next thought. When talk of

ability turns to availability, think of Ex-Cell-O for the



59-32

pre-requisite to performance...precision.

EX-CELL-O FOR PRECISION XLO

EX-CELL-O CORPORATION
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Aircraft Division

MAN AND MISSILES FLY HIGHER, FASTER AND SAFER WITH PARTS AND ASSEMBLIES BY EX-CELL-O AND ITS SUBSIDIARIES: BRYANT CHUCKING GRINDER CO., CADILLAC GAGE CO., MICHIGAN TOOL CO., SMITH BEARING DIV.

Now Norden-Ketay engineers are talking in terms of uncooled 500-deg C operation in the very near future.

Norden-Ketay's high temperature contract called for the development of a synchro, a servo motor, and a potentiometer that would be able to operate in a nuclear radiation environment from —65 to +300 deg C. The worst design problems were: finding radiation-resistant materials with compatible coefficients of expansion; making the electric connections; and matching the junction materials so as to avoid a thermocouple effect.

SIZE 15 nuclear-resistant potentiometer developed by Norden-Ketay is supposed to operate for 100 hours while exposed to 10^{11} neutrons and 10^{18} gamma rays per cm^2/sec. It has 10 K resistance, a 330-deg electric angle of operation, and 0.25 per cent linearity.

EXPANDED materials research facilities are needed for high temperature nuclear component development work, says Norden-Ketay. Such facilities must be able not only to evaluate manufacturers' claims but also to come up with new material combinations.

Norden-Ketay admits to working on 500- and 600-deg C component development programs. The new ovens it bought recently can go up to 1000 deg C.

Solar, nuclear or chemical energy to be used by Allison engine

SATELLITE combustion engine that can use solar, nuclear, or chemical energy is being developed by Allison under an agreement with Philips Gloeilampenfabrieken, of Holland, and North American Philips Co. According to Allison engineers, the powerplant will be able to operate unattended for at least two years.

A lab model of the powerplant already has been operated successfully on solar radiant energy. With one cubic inch displacement, the engine can produce 1½ hp with an efficiency of around 40 percent.

A CLOSED-CYCLE TYPE, the engine under development at Allison consists of a displacement transfer piston and a work piston that reciprocate in a single cylinder. The cycle begins with the application of external heat, produced by any of a variety of combustible gases or organic materials or by harnessing the sun's energy. A special 20-ft-diameter Fresnel lens is needed, if solar energy is the source. It concentrates the sun's rays and focuses the energy on a "window" in the engine's heat trap.

Rapid expansion and cooling of air, helium, or hydrogen sealed in the engine energizes the pistons. The engine operates at a constant speed of about 3600 rpm while driving two 12,000-rpm alternators. Its electric output is large enough to power satellite instruments.

CS drive stands up to 200 hr under radiation

TWENTY-KVA HYDRAULIC constant-speed drive made by GE's Aircraft Accessory Turbine Dept. has successfully completed a 200-hr test in a radiation environment. The test was run as part of GE's aircraft nuclear powerplant development program.

The drive performed satisfactorily and maintained close frequency control under various load conditions, says GE. It is a model of the unit used on the McDonnell F4H. Tungsten carbide cylinder liners have been substituted for the conventional liners and radiation-resistant seals substituted for all organic sealing materials.

FIRST POWERED X-15 flight lasted 10 minutes. The plane was released at 38,000 ft and went through a series of minor control maneuvers before landing at over 200 mph. The two 6000-lb thrust engines used for this flight will eventually be replaced by 50,000-lb thrust XLR-99s.

"BACKPACK" study underway at Aerojet-General for the Army will explore the feasibility of using small rocket lift devices to power combat troops on special missions. The broad seven-month study program will cover dynamic stability, propellant energy sources, and a system analysis to determine the best configuration for different missions.

The system analysis will deal with the rockets' size, weight, location and number of nozzles, flight controls, and thrust as well as with human response and reaction time and safety. The dynamic analysis will determine flight durations and maximum speeds and accelerations. The effects of wind gusts, loss of stability, in-flight rocket malfunction, and other disturbing phenomena also will be considered.

more on page 34

The T2J has "THE DUTY"

to train the Navy's jet-age pilots for years to come

Fifteen years ago, a pilot was trained to fly the top performance plane of the day—360 mph.

Today he must be trained in the same time-span to handle airplanes four times faster than that—Mach 2 and up. That's why the Navy needed a new trainer . . . a jet airplane to prepare its pilots for the ever-increasing performances of the jet age.

Now the Navy has that trainer—the T2J Buckeye . . . designed and produced to meet Navy specifications by the Columbus Division of North American Aviation.

The Buckeye's wide range of capabilities opens a new dimension in basic flight training. Its range of speed—from a stall speed of 85 mph . . . to maximum 500 mph—makes it possible to train a cadet pilot in a jet airplane straight through from primary to advanced.

And the T2J does more than fill the *present* requirements of the Navy's flight training program. Its advanced capabilities will make it the mainstay of the Navy jet training program for *many years to come.*

Because the T2J is the only jet trainer specifically designed to meet the Navy's basic training requirements, it means a broader, more efficient training program to meet the ever-higher standards of pilot proficiency demanded by the Navy.

THE COLUMBUS DIVISION OF NORTH AMERICAN AVIATION, INC.
Columbus, Ohio

OPERATIONAL UNDERGROUND launching system for the Titan ICBM is being produced by American Machine & Foundry. The company will build, install, and test the first 18 systems. Fuel storage, the guidance antenna, and the electronic control centers are all underground on the Titan.

HIGH TEMPERATURE core form material was developed by GE's Flight Propulsion Lab, of Evendale, Ohio. It consists of refractory cerium sulfides, which make it possible to raise casting temperatures beyond the melting point of the glass and alumin-silica-magnesia cores now in use.

Cores of various sizes and shapes have been made for GE by National Carbon. Inner cores of sulfide on molybdenum and tungsten have also been produced.

The big advantage of cerium sulfides, says GE, is that they have very high melting points and low volatility. They also have a high modulus, are non-wettable, show good thermal conductivity, and are chemically inert to metals. Nevertheless, they can be dissolved relatively easily by mild dilute acids.

New methods of power transmission to be used in electric system

ADVANCED AIRCRAFT ELECTRIC system for BuAer is being worked on by GE's development labs at Waynesboro, Va., and Erie, Pa. New methods of static power conversion will be used in the system, says GE, and will eliminate the need for mechanical variable-ratio transmission. The high frequency power generated by a variable-speed alternator will be converted to constant-frequency 400-cycle power.

The variable-speed alternator will be connected directly to the aircraft engine. The static frequency changer may be installed anywhere in the plane. The system output will provide constant-frequency, constant-voltage power to operate electronic equipment, lighting, heating, and comfort loads.

•

GE-LYNN PROPOSED an aft-fan version of its J85, which will deliver 4000 lb takeoff thrust. The new engine, sponsored with company funds, will weigh 585 lb, be 69 in. long and have SFCs of 0.69 lb/lb/hr. at takeoff and 0.97 at normal continued thrust (Mach 0.8 at 36,000 ft).

THE ENGINES of the two Hound Dogs carried by a B-52 can be started on the ground to assist in the plane's takeoff, revealed Lt. Gen. Roscoe Wilson, USAF Deputy Chief of Staff for Development.

Wilson also disclosed that the air-launched Quail decoy missile is scheduled for operational use by SAC within the next few months.

Materials strengthened by new heat treat, it's claimed

NEW HEAT TREAT method developed by Research Development Corp. of America, of Gardena, Calif., is claimed to revolutionize materials properties. Coupons of 4130, executive vice President Jack Taub told SPACE/AERONAUTICS, that were heat-treated by RDCA showed a UTS of 255,000 psi and a yield strength of 241,000 psi, with 13 per cent elongation and 55 per cent area reduction. Other results cited by Taub: 4340—335,000 psi UTS, 312,000 psi yield, 11 per cent elongation, 28 per cent area reduction; Vascojet 1000—325,000 psi UTS, 309,000 psi yield, 13.3 per cent elongation, 37.5 per cent area reduction. These values, Taub pointed out, are guaranteed minimums.

Parts treated by RDCA's method include pressure vessels and control surface components. In one case, a 17-4PH cast aileron part about three inches wide and one foot long was successfully treated to break up free ferrites, Taub reports. In another case, an eight-inch diameter pressure vessel of AMS 6434 steel was processed to 280,000 psi yield strength and 300,000 psi UTS.

THE MAXIMUM size that RDCA can process at present is about 18x9x9 in. However, says Taub, there's no limitation on the process. You could build installations to take parts, say, 100 ft wide, at a cost no higher than that of standard furnace equipment, he reports.

•

UNIVERSAL solar-electric power system for satellites will be developed by Hoffman under a WADC contract. The design goals call for 100 W continuous power output and 500 W peak. Silicon solar cells similar to those used in Vanguard and Explorer VI will be used. The system will be packaged within the launch vehicle at takeoff and unfold in orbit.

Hoffman says the project, for which $600,000 has been allocated as a first installment, is mainly exploratory and not tied to any particular space system.

Check Employment Inquiry Form on Page 217

calendar

November 2-4—National Midwestern Meeting on New Frontiers in Aviation, Institute of the Aeronautical Sciences, Hotel Lassen, Wichita, Kan.

November 2-5—Fall Meeting of The Metallurgical Society of the American Institute of Mining, Metallurgical, & Petroleum Engineers, Morrison Hotel, Chicago.

November 2-5—Fall Meeting, Western States Section, Combustion Institute, AS Bldg., Los Angeles, Calif.

November 3-5—11th Annual Mid-America Electronics Conf., Institute of Radio Engineers' Kansas City Section, Hotel Muehlebach, Kansas City, Mo.

November 4-6—National Automatic Control Conf., IRE, American Institute of Electrical Engineers, Instrument Society of America, American Society of Mechanical Engineers. AIEE is conducting a parallel Control System Components Conf. on Nov. 5-6. Sheraton Hotel, Dallas, Tex.

November 8-13—International Rubber Technology Conf., ASME, ACS, & ASTM, Shoreham & Park Plaza Hotels, Washington, D.C.

November 9-11—Fourth Instrumentation Conf. & Exhibit, IRE Professional Group on Instrumentation & Atlanta Section, Biltmore Hotel, Atlanta, Ga.

November 9-20—13th Annual Air Transportation Institute, American University's School of Business Administration, Washington, D. C.

November 11-13—16th National Meeting, Operations Research Society of America, Huntington-Sheraton Hotel, Pasadena, Calif.

November 16-19—14th Annual Meeting and Astronautical Exposition, American Rocket Society, Sheraton-Park Hotel, Washington, D.C.

November 16-20—Automation Show & Conf. on Materials Handling, New York Trade Show Bldg., New York, N. Y.

November 16-20—20th Annual Convention, National Aviation Trades Assn., Hotel Montleone, New Orleans, La.

November 17-18—National Turbine-Powered Air-Transportation Meeting, ral History Building Auditorium, Calif.

November 17-19—34th Meeting, Aviation Distributors and Manufacturers Assn., Diplomat Hotel, & Country Club, Hollywood, Fla.

November 18—Fall Meeting, Eastern Division of Society of Aircraft Materials & Process Engineers, Sheraton-Carlton Hotel, Washington, D. C.

November 19-20—Seventh Annual Aircraft & Missile Division Conf., American Society for Quality Control, Sheraton-Dallas Hotel, Dallas, Tex.

November 23-25—Division of Fluid Dynamics, American Physical Society, University of Michigan, Ann Arbor, Mich.

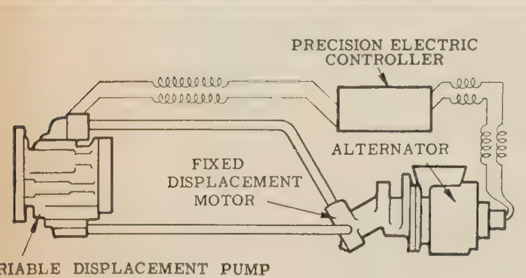
PICTURE CREDITS: Cover, p. 5—S/A; pp. 39-43—AIA, Convair, U.S. Industries, Fansteel; pp. 44-47—Rocketdyne, Lockheed Aircraft; pp. 48-51—North American Aviation, Cincinnati Milling Machine; pp. 54-59—Convair; pp. 60-62—North American Aviation, General Electric; pp. 63-66—Linde, North American Aviation, Solar Aircraft; pp. 73-80—AIA, Hi-Shear Rivet Tool, Lockheed Aircraft, Battelle Memorial Institute; pp. 85-92—AIA, Battelle Memorial Institute, Marquardt Aircraft, USAF, Convair; pp. 97-110—Northrop; pp. 114-116—Bristol Siddeley Engines; pp. 117-121—Chicago Aerial Industries; pp. 123-130—General Electric; pp. 135-138—Rocketdyne, Harman Equipment, Cuno Engrg.; pp. 143-154—Ryan Aeronautical; pp. 164-168—Servomechanisms.

New VICKERS building block concept applied to

CONSTANT SPEED DRIVES

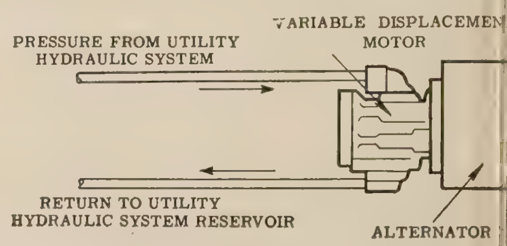
for 400 cycle A.C. electrical systems

1 Unlimited Versatility
2 High Efficiency
3 Fast Delivery
4 Low Cost



Frequency control ± 0.1%. Uses electronic frequency controller to regulate pump displacement. System pressure is function of load.

Frequency control ±0.25%. Uses load sensitive system to match infinitely variable electrical load. System pressure is constant, flow demand is load dependent.



• Using this "building block" construction, Vickers Constant Speed Drives are assembled to exact requirements from the abundance of Vickers standard and proven components. Practically any characteristics you need can be quickly adapted to the existing Vickers product mix. These include:

FREQUENCY CONTROL
± 3% with hydraulic control
± 0.1% with electronic control (or better if desired)

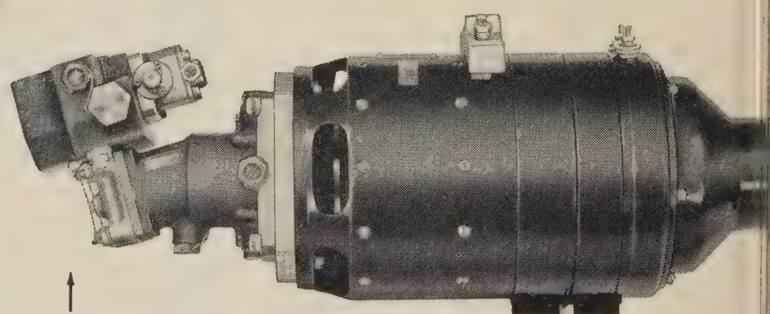
VERSATILITY
1 to 75 hp with standard hardware
Flexibility of package shape and location

HIGH EFFICIENCY
Volumetric efficiency of either pumps or hydraulic motors is 96% at 3000 psi. This together with optimum matching of components results in very high system overall efficiency.

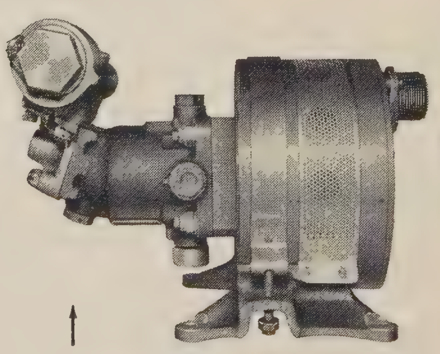
MINIMUM WEIGHT
Significant optimization engineering can be applied to your system design considerations from similar Vickers application experience.

OVERLOAD CAPACITY
Depending upon system requirements, overload capacity of from 120% to 200% can be provided.

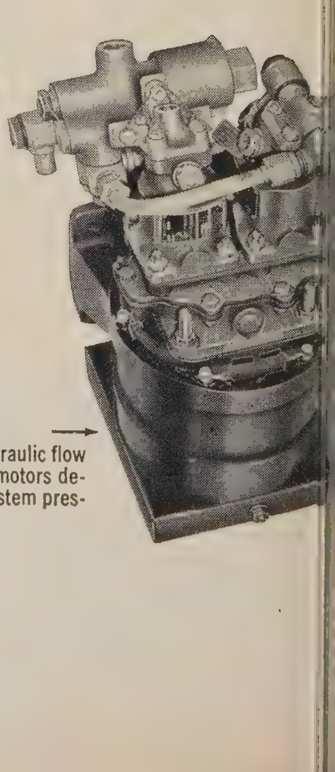
For further information, write for Bulletin SE-100.



Frequency control ± 0.1%. Uses electronic frequency signal to trim hydraulic flow control. System pressure is constant.



Frequency control ± 3%. Uses hydraulic flow control only. System pressure is constant.



Frequency control ± 3%. Uses hydraulic flow control to supply single or dual motors depending upon load variations. System pressure is constant.

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production
& materials
engineering

1

A Space/Aeronautics special report on the state of the art and the technical outlook in two crucial aerospace technologies

Production and materials engineering:

"exotic" materials trigger production "revolution"

by Irwin Stambler, Associate Editor & Project Leader

THE FOREMOST trend in aerospace production is that there is going to be less production. Aircraft production orders used to run in the thousands, but even "large" orders for future designs will be only in the hundreds. And once we build large spacecraft, they'll all probably be "one of a kind," just as are today's ocean liners.

Even with a low overall volume, though, the production tools and methods needed for the new designs will be far more complex than anything the industry has used in the past. In fact, a production "revolution" is in the making—if we are to fabricate the many new materials now coming out of R&D, we will have to change just about every aspect of our design-production practices and theories.

One striking change is shown up by the growing interdependence of production and materials. Once these were two separate fields. The designer selected the materials, and then it was up to the production people to make the parts.

Now, the two areas are becoming inseparable. With the high strength alloys of today and tomorrow, the designer can't specify just any material—he must first find out if the material of his choice can be fabricated into the shape he wants.

In fact, F. A. Monahan, manager of manufacturing development and process

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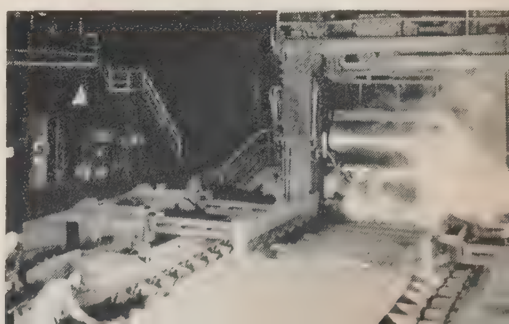

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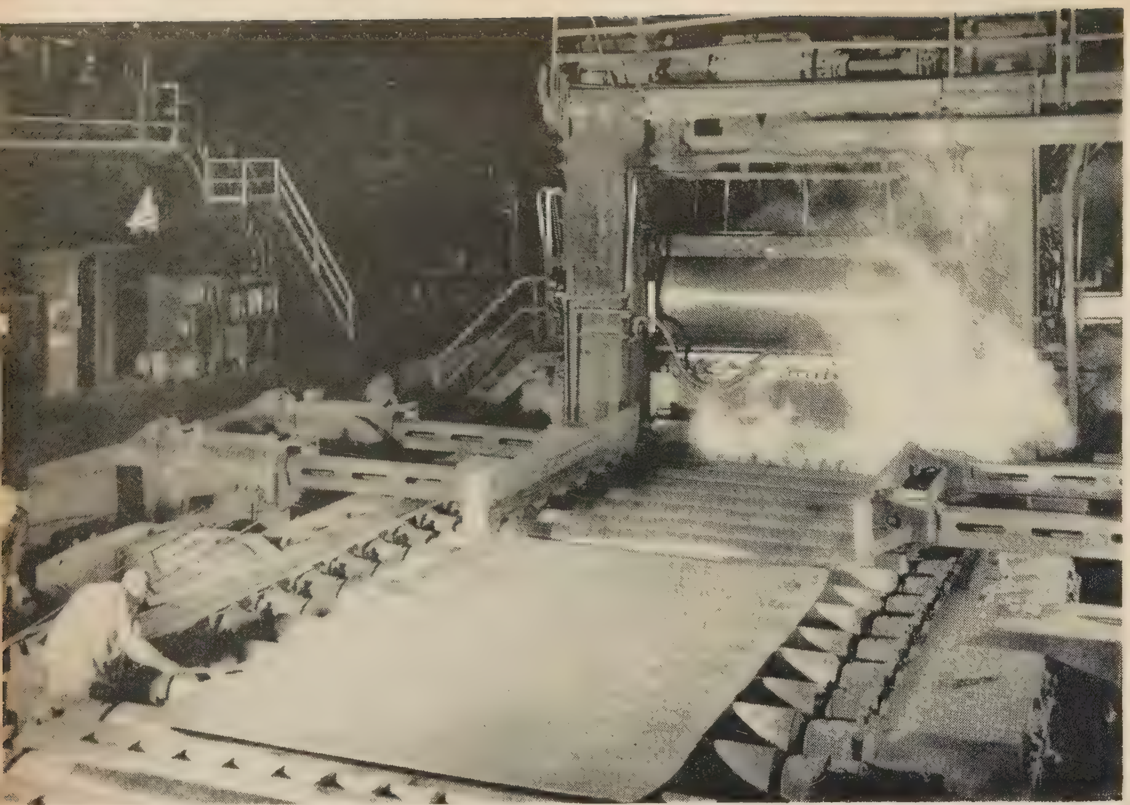
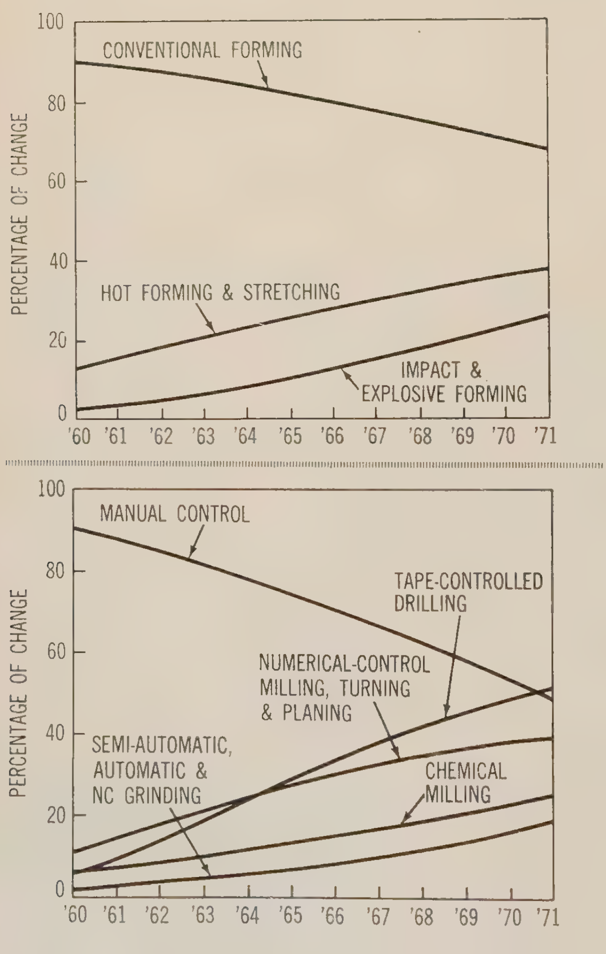


NEW ROLLING process for producing thin, close tolerance, wide steel sheets, developed by U.S. Steel, is prime hope for meeting future structural needs. USAF earlier this year gave U.S. Steel contract for development of production methods.



specifications at Convair-San Diego, told SPACE/AERONAUTICS that in many areas manufacturing R&D must lead the designer. Naturally, Monahan explains, the designer wants to design something that can be made. But with the newer materials he can no longer look up the data he needs in a handbook or get them from test coupons. A molybdenum forging, for instance, has properties different from those of a molybdenum test coupon (because of oxidation, inclusions, etc.). As a result, Monahan says, the trend in manufacturing R&D is to make typical sheet samples, castings, etc., from new materials and so provide engineers with the necessary data before they try to design new parts.

Another example of the impact of new production approaches on design is numerical machining. In some cases, this technique lets you make parts without drawings. Take a wind tunnel model that was recently turned out by the manufacturing department of a major aerospace firm. An aerodynamicist supplied the aerodynamic formulas for the model, manufacturing plotted them out on tape, and the model was produced directly from the tape.

Numerical control also has brought about a change in part parameters. In the past, production engineers preferred straight lines on parts, because of factors such as the limitations of manually run milling machines. Now manufacturing prefers curves—with tape control, it's as easy to go one way as the other.

Perhaps the major continuing trend in production is away from forgings, castings, machined parts, etc., and

FIGURE 1: Trends in material shaping (top) and material removal as forecast by the Aerospace Industries Association on the basis of an industry survey.

toward the wider use of sheet material. In its 1959 forecast of trends and requirements, the Aerospace Industries Association (AIA) estimates—on the basis of an industry survey—that almost half of all structural vehicle empty weight will be sheet forms by 1965-70, as against 30-33 per cent today.

A prime reason for this trend lies in the difficulty in machining and shaping such materials as the superalloys and refractory metals. Also, the present trend from light metals to steels has outmoded even the most powerful production equipment in use today. Producibility engineers at a number of companies told SPACE/AERONAUTICS it would cost a tremendous amount of money to convert such units as the 35,- and 50,000-ton heavy presses to make the type of steel forging needed for future designs. They emphasize that you can't forge as closely with steel as with aluminum—the dies won't stand up.

One engineer said that, in machining a forging, the job is 50 times as complex with a steel part as with an aluminum part. Precision steel forgings are the theoretical answer. But the same engineer has a very practical objection: How can we get precision steel forgings when we can't even get true precision aluminum forgings?

Better mechanical properties expected

Figure 2 shows some of the trends in application forms over the next 10 years. Considerable improvement in mechanical properties is expected for most cast and wrought materials. A major swing to welded structure (including honeycomb) is also expected by 1970. Much of this particular trend involves the wider use of composite structure in which similar or dissimilar materials are combined to take advantage of each material's specific properties.

Composite structures pose considerable manufacturing problems. For instance, 17-5PH and AM 355 both have growth factors at high temperatures—but different ones. And that's a relatively simple case.

How to hold composite assemblies within tight tolerances is a key problem. As Monahan points out, upcoming designs call for tolerances of less than 0.0005 in. on sheets on the order of 20x20 ft. At present, incidentally, such sheets aren't even available, and it's necessary to weld sections together and then planish to tolerance. A solution for this particular problem may be provided by U.S. Steel's current work on rolling large, thin sheet.

How will the composite structures be joined? Much of the research on this question is aimed at eliminating brazing. It's hard to put inserts in brazed core, and it's hard to tie the core into closure members. Also, of course, right now welding looks more promising for large-scale production.

However, as George D. Cremer, senior staff engineer at Solar, told SPACE/AERONAUTICS, researchers and designers have only begun to tap the potential of brazing processes. So far, he states, nobody has come up with a welding method that can compare with brazing. New brazing alloys, Solar engineers believe, will insure a continued edge for brazing.

more on next page

THIS SPECIAL REPORT deals with two aerospace technologies that have become inextricably linked in recent years: materials and production. Its principal aim is to show just how the continuing improvement of materials performance is affecting the production picture, requiring new methods in the use of today's tools and, above all, the development of radically new machines and processes.

This report is the result of a nearly year-long effort by a team of S/A editors including Vic de Biasi, Jim Holahan, and Bern Kovit and headed by Irwin Stambler, our specialist on materials and production.

A limited number of reprints of this report is available at $1 per copy. Reduced rates apply for bulk orders of 50 copies or more. Address orders and remittance (no stamps, please) to: Reprint Dept., SPACE/AERONAUTICS, 205 E. 42nd St., New York 17, N.Y.

S/A's special report on production and materials engineering begins with this article. Its other features are:

Please note that the report's last four features, all of which cover electronic subjects, are separately grouped in this issue's Aerospace Electronics section.

Randolph Hawthorne Editor

Irwin Stambler

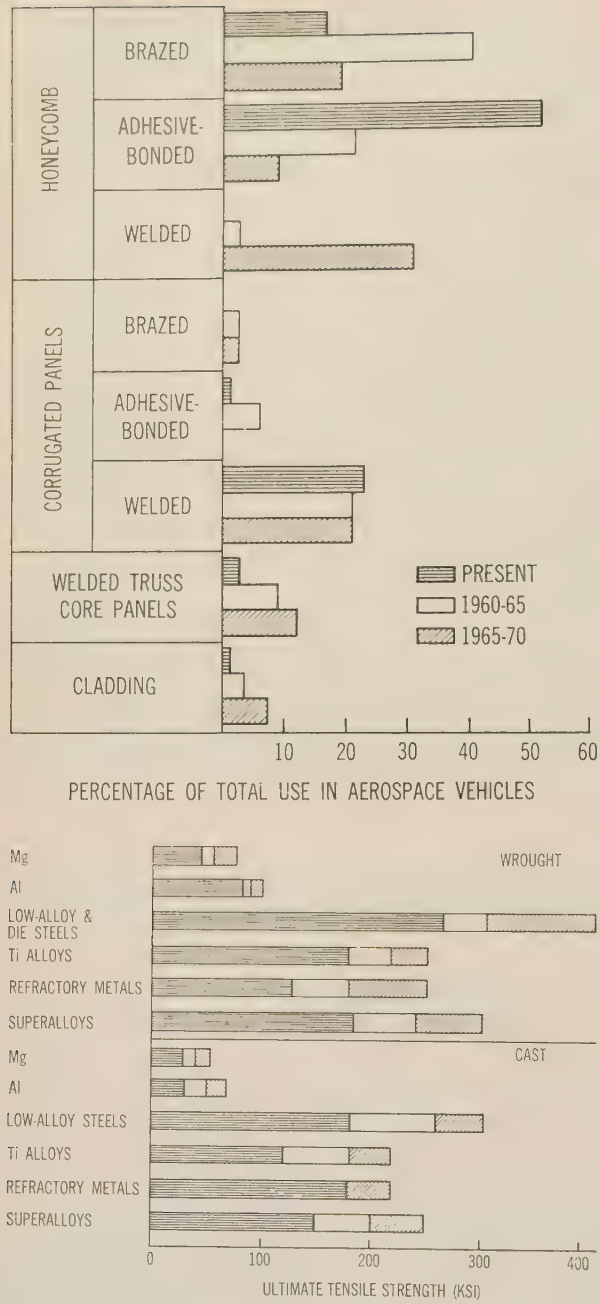


FIGURE 2: Increases in mechanical properties of alloys and changes in structural applications as forecast by AIA.

Boeing manufacturing engineers believe that breakthroughs in inorganic chemistry will bring bonding back into prominence in high temperature applications. Their company's researchers are working on ceramic core structures. The AIA study reports a belief that ceramic adhesives will be perfected for applications beyond 600 deg F. Bonding of steels is also expected to become commonplace.

Because of the increasing emphasis on very close tolerances, we are developing forming methods that give parts with nearly final dimensions. As *Figure 1* shows, conventional forming methods are giving way to new techniques. Precision castings, forgings, and extrusions must be developed in a wide range of materials. High energy forming, hot- and cold-shear spin forming and hot-forming and -stretching of sheet materials will play an increasingly important role in future production.

For R&D forming of large sheet metal parts, Martin is using a 6500-ton Loewy Marform press with rubber pad pressures of up to 10,000 psi to make 25x25-in. parts out of ⅜-in. alloy steel. For trapped rubber forming, Boeing is using a press with an 18-in.-diameter-head.

AIA's Equipment Committee has suggested to the services that a trapped-rubber unit be developed with a 48-in.-diameter head. Martin and Loewy are thinking about developing equipment with which to form 95-in.-diameter blanks.

Despite the trend to welded and brazed sheet structure, material removal will still be a key factor in future designs. The vastly increased use of refractory metals, steels, superalloys, ceramics, and plastics in aerospace vehicles will result in an estimated reduction of 30 per cent in material removal by conventional machine milling. Even so, AIA reports, machine milling will still be the biggest material removal operation.

The new alloys, of course, call for much more powerful and rigid machine tools. Boeing, for example, reports that three time more power is needed with steel than with aluminum.

Processes will be automated

As *Figure 1* shows, the trend in material-removal equipment is toward relatively specialized, numerically controlled semi-automatic and automatic machines. The new materials also call for much wider use of new processes, including chemical milling, ultrasonic and electric-discharge machining, abrasive grinding, etc. Finally, much closer temperature control will be needed.

An important need, AIA says, is the development of methods for casting, forming, and machining cermets. These are expected to require ceramic, ceramic-faced, or diamond-shaped tools. Many of the chipless machining methods, of course, are already being used to work these materials. The increased use of plastics, ceramics, etc., also has brought about a trend toward specialized equipment for filament winding, wrapping and curing.

Cutting tool R&D is aiming both at developing new designs and materials and at making more efficient use of current tools. An example of the latter approach is given by the efficiency studies run at Lockheed (see *"Machine Tools: From New Techniques to New Designs," p. 44*). Like Lockheed, Boeing is going to climbing cuts. (In the past, you cut into material by rotating into it; now you rotate out of the material.)

Convair has a solid ceramic cutter in the R&D stage that it hopes can be produced very cheaply—so that it doesn't have to be resharpened when it's worn but can be thrown away. An expendable tool, Monahan explains, would be particularly good for tape control work, in which you lose human feel—the operator can't tell (by chips, smoke, etc.) what condition his tool is in and doesn't always get it out in time for resharpening.

A conventional milling cutter costing around $50 can be resharpened about five times before it must be discarded. So an expendable ceramic tool costing $5-10

would represent a considerable production saving.

Convair believes it should be able soon to turn out its present ceramic cutter at a rate of 1000 per hour (molded to size). In R&D work, aluminum oxide cutters have been used successfully to cut materials of up to R_C 32. Quarter-inch cuts have been made easily at that hardness, Monahan reports.

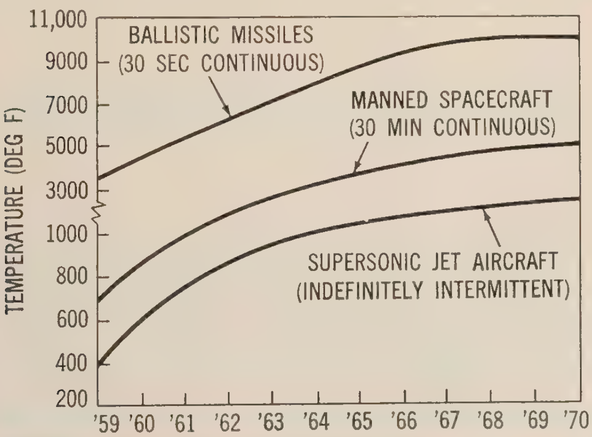
Better soldering for circuit cards

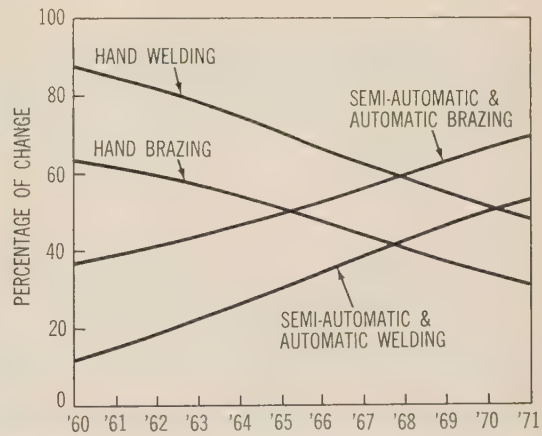
In electronic production, better machine soldering methods are a prime requirement. Icicle control, joint quality, and inspection all pose problems in soldering, AIA's survey revealed. It also showed that new processes and equipment for solder termination will be needed for improved circuit cards to be used in the 700-deg F range. By 1970 the temperature range is expected to extend to 1000 deg F and require flexible and/or multi-layer circuit cards and associated equipment. Mechanical or welding tools or combinations of these designs, says AIA, will probably be needed for lead termination for the 1000-deg F range.

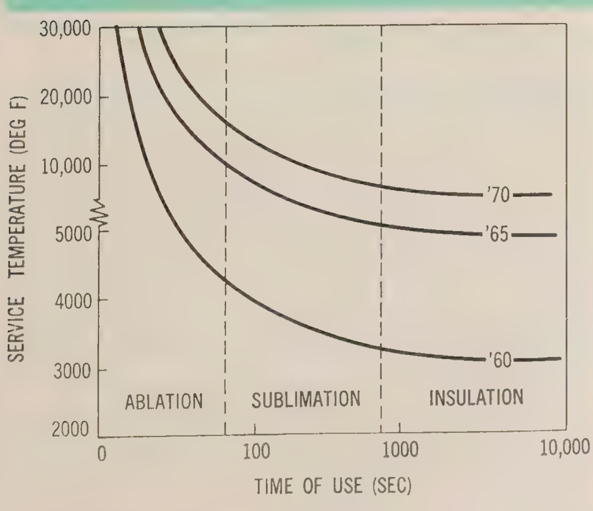
The properties of the new high strength and temperature materials clearly show the increasing need for tailoring production methods and equipment to materials parameters. However, even though the old standbys of the aerospace industry, the light alloys, will account for only a small portion of the vehicle of the future, this doesn't mean they won't have an important role to play. For instance, it appears that in such designs as space vehicles and stations assembled in orbit metals like aluminum may make up a significant amount of structure. The increased need for mobile ground support equipment also may lead to new types of light structures, such as paper honeycomb faced with aluminum.

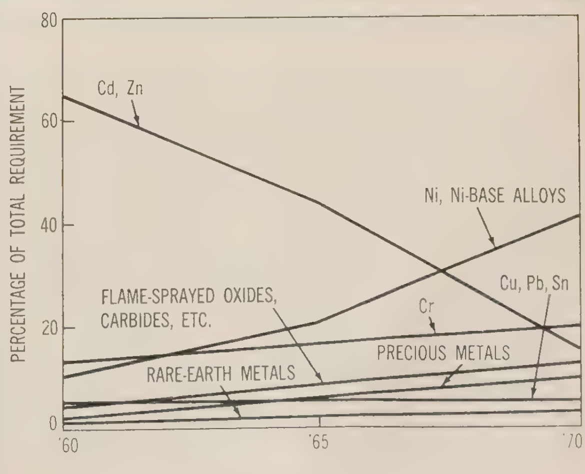
All in all, it still holds true that there's practically no material that won't find some use in future aerospace projects. Besides the materials mentioned here, of course, even more unusual ones are on the horizon—in particular the so-called combined systems, materials made of almost any combination of metals, plastics, and ceramics. Production engineering clearly must prepare for fundamental changes.—End

ELASTOMER temperature properties (top left) are expected to improve. Silicones, urethanes, and fluorocarbons are prime hopes. Top right: Trends in brazing and welding as forecast by AIA. Bottom left: Improvement in ceramics and cermets expected for the next decade. According to AIA, ceramo-plastics will be used for ablation; graphite, sublimation ceramics, and metallo-ceramics for sublimation; and solid-body ceramics, metallo-ceramics, cermets, reinforced refractory ceramics, and flame- and plasma-sprayed ceramics for insulation. Bottom right: Plating material use trends as forecasts in AIA survey.









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Machine tools:

from new techniques to new designs

More efficient methods for the sixties, radically new machine tool configurations for the seventies

Tomorrow's Machine Tools

by W. E. Stewart, Manufacturing Engineer, Manufacturing Analysis Group, Rocketdyne Div., North American Aviation, Inc.*

NEW CONCEPTS clearly are needed if machine tool builders are to keep pace with the fabrication needs of tomorrow's missiles and spacecraft. The increasing use of large, integral components for such systems as rocket engines will require larger versions of many existing machines. The fact that the larger machines will also have to be more accurate may impose entirely new design approaches.

The manufacturers of advanced vehicles somehow must find a way of machining the new hard, tough, and stringy material. And the answer may lie not in heavier machines, but in the application of some of the same strong, stiff metals that brought about the machining problem in the first place.

The versatility and speed of numerically controlled machines have paved the way for new developments. More effective configurations, virtually impossible to machine by conventional methods, will result as design and manufacturing engineers pool their ideas.

It's quite possible that the aerospace plant of the seventies will rely largely on vertical lathes, which avoid the "droop" problem in large but fragile components

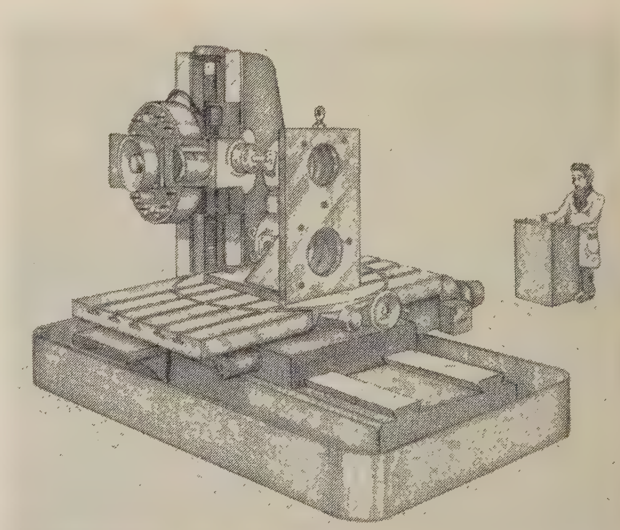

FIGURE 1: Numerically controlled milling-drilling-boring machine of the seventies with built-in rotary table and capacious tool storage drum.

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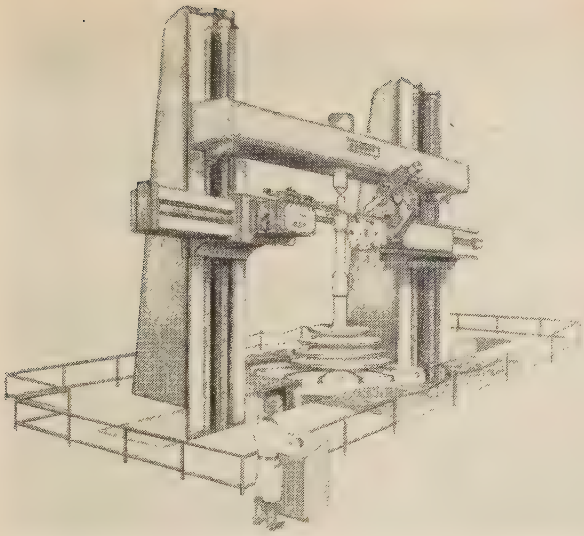


FIGURE 2: Futuristic vertical turret lathe using automatic dimensional control and a temperature- and load-sensing unit for feed and speed control.

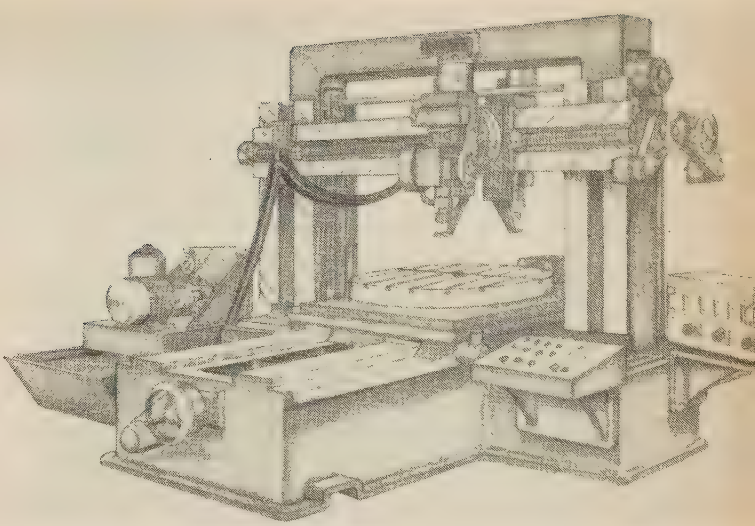


FIGURE 3: Drilling machine of the near future with one head for heavy-duty work and another for "load-sensitive" drilling of small, precise holes.

(*Fig. 2*). Most of the dimensional-error problem may be overcome through the use of optical and electronic sensing units, now generally restricted to high production work or of complete numerical control.

The machining of hard tough metals will no longer be a problem. Infrared sensing units will measure temperature and load at the cutting edge and automatically keep speeds and feeds at optimum values.

"Building block" milling machines (*Fig. 1*) with infinitely variable, gearless drives using variable-pitch turbines or magnetic clutches will be part of our plant of the future, and so will be gas film lubrication systems. The machines will have built-in provisions for localized heating of the workpiece, so that the fixturing medium can be quickly frozen or melted when fragile pieces are milled.

Ultra-high-speed drilling machines, which will remove metal so rapidly that special chip-packaging systems will be needed, will be standard equipment (*Fig. 3*). Drilling machines will produce holes in what is now thought to be "unmachinable" stock at fantastic rates by electron-beam bombardment . . .—End

Machine Tools Today

by Robert L. Vaughn and George R. Clemens, Producibility Methods Engineering Dept., Lockheed Aircraft Corp.*

ALUMINUM and other lightweight alloys still represent a large portion of today's typical aircraft structure. Present general-purpose machine tools are generally considered satisfactory for making complex aluminum parts. However, in recent years special-purpose machine tools have been used to speed up the production of such parts.

Typical special-purpose machines are the spar, skin, and cavity mills; the one-, two-, and three-dimensional profilers; routers; shapers; and all types of template- and model-tracing machines. Some of these machines, such as the spar mills and routers, are modifications of wood-working equipment. Others are similar to general machine shop equipment, but have higher spindle speeds and a lighter construction.

Few of the special-purpose machine tools could be economically converted for use on the new high strength materials. Obviously, rugged, low-to-high speed, high horsepower machines will have to be used. AMC-sponsored R&D at Lockheed indicates that it may prove possible to machine newer alloys if very high speeds are used.

Future machine tools will be vibration-free, using new ways of transmitting energy to the cutter and drives. It's conceivable that air bearings or electromagnetic fields to support spindles will do away with bearing problems. Hydraulic motors would meet some of the requirements for high power spindles. Electric motor drives with higher powers and speeds are being developed. Flywheels could be used to store energy and supply the power needed to cut today's metals at higher speeds.

Machines need more rigidity—both for today's and tomorrow's operations. Possibly aircraft design methods might be used to increase rigidity without adding

more on next page

* Lockheed Aircraft Corp., California Div., 2555 N. Hollywood Way, Burbank, Calif.

·EDS AND SPEEDS FOR WORKING AM-350 STEEL

Diameter (in.)	Feed or Chip Load (in./rev or in./tooth)	Rc 36 Speed (sfm)	Rc 36 Est. Life (lineal in.)*	Rc 47 Speed (sfm)	Rc 47 Est. Life (lineal in.)*
	Drilling				
.250	0.003	30	75	10	20
.375	0.004	40	100	10	20
.500	0.005	40	100	15	20
625	0.006	50	120	25	20
.750	0.007	55	120	30	20
875	0.007	55	120	30	20
.000	0.008	60	150	35	25
.250	0.008	60	150	35	25
.500	0.008	60	175	40	25
.750	0.008	65	175	40	30
000	0.009	65	175	45	35
500	0.010	65	190	45	40
000	0.010	65	190	45	45
	Reaming				
025	0.007	5	75	5	25
375	0.007	5	100	5	35
500	0.008	5	150	5	40
625	0.010	8	200	8	45
750	0.012	8	200	8	50
875	0.014	8	200	8	50
000	0.016	10	200	8	50
250	0.018	10	210	10	55
500	0.018	10	210	10	55
750	0.018	12	210	10	55
000	0.018	12	220	10	55
500	0.018	12	220	10	55
000	0.018	12	220	10	55
	Milling				
Flute Ball ıd Mill	0.001	100	40	20	20
Flute Square ıd Mill	0.003	130	60	40	45
Flute Ball ıd Mill	0.0025	100	40	40	20
Flute Square ıd Mill	0.0025	130	60	45	50
Flute Ball ıd Mill	0.0005	95	50	25	20
Flute Square ıd Mill	0.001	100	70	50	40
aggered ıoth Full Side 1S-HSS)	0.002	100	200	60	75
aggered ıoth Full Side 1S-HSS)	0.0025	120	150	70	80
ycutter ırbide	0.003	150	125	80	100

weight. A threefold increase in the modules of elasticity may be obtained by using frames of welded steel instead of cast iron. This approach is already being used by some machinery manufacturers.

Carbide cutting tools were introduced in the late thirties and cemented oxides about 1955. The result was the development of machine tools with increased power and higher speeds. Better cutting tools have since been designed that allow further improvements in machine capabilities. Tool performance has been raised by:

- better carbides for steel cutting;
- disposable carbide inserts that have several cutting edges and require no grinding;
- mechanical clamping methods, which eliminate brazing;
- insert-type cermet tools for single- and multiple-tooth cutters;
- better grades of high speed steel.

Alloying and heat-treat cause definite changes in the physical properties and metallographic structures of the metals. These in turn cause cutting tools to perform erratically. In the annealed condition, some alloys are "gummy." The cutting heat causes them to weld to the cutting tool, and the result is minute chipping of the cutters. These alloys would machine better if they were heat-treated to R_C 32-42 and carbide or even high speed tool steel were used for the cutters. Cutting limitations must be considered even when you are using the so-called "proper grade." Increased cutting pressures limit the cut size that you can take without tool breakage. When steel alloys are heat-treated to more than R_C 46, a tempered structure containing some martensite is produced whose machinability is sharply reduced. Such alloys are sometimes extremely abrasive; with some setups and cutters, therefore, very high speeds and feeds cannot be used.

At the reduced cutting rates needed for highly heat-treated alloys, the present cemented-carbide cutting tools may not be practical. The reasons lie in the grain structure of these tools and in the cutting heat—chips weld more readily to carbide than to high speed steel. Particles of the work material are forced into the grain boundaries by continued pressure and impact, and the tool fractures prematurely.

A study of a production run on high strength (R_C 59) landing gear parts, for instance, revealed that a chip load of 0.0005 in. per cutter tool at 30 sfm gave the longest tool life. As *Figure 5* shows, high speed steel cutters in this case proved twice as good as carbide cutters.

Cost dictates the tool selection

Economics usually dictates the use of a particular cutting tool. Carbides shouldn't be used for form cutting. Shop practice has shown that inserted tooth mill cutters with a corner radius of 0.125 in. or more break down fast when used to machine highly treated steel (R_C 46 or more).

High speed cutting tools can take higher shock loads than most carbide types. For this reason, their life is 2-3 times longer. There are many cases in which the cost of carbide tools isn't justified. However, sometimes the higher floor-to-floor time offsets the lower initial cost and ease of grinding for high speed cutters.

A promising new development is the use of electro-sparking for depositing carbide particles on high speed steel cutting tools. It's claimed that, in several tests,

tool life was increased by up to 400 per cent.

In practice, there exists a limit and a minimum value for the theoretical chip thickness in a given machining condition. If the cut isn't deep enough the cutting edge of the tool will elastically deform and slide over the material without cutting (*Fig. 4*). The machined surface is cold-worked, and hard spots are produced that must be removed before another cut is made.

Cutting depth is especially critical on work-hardenable alloys like AM 350. It is now common practice to leave at least 0.06 in. of stock to be removed for finishing after heat-treat.

A recent study on AM 350 showed that, except for severe work-hardening tendencies in the heat-treated condition, the alloy can be machined much as is SAE 4340. Specimens at R_C 36 and 47 required cutting tools with the clearances and rake angles normally used on steels of comparable hardness (see *Table*).

Machining of the R_C 47 specimens showed that certain types of standards cutting tools worked well. The following recommendations were formulated:

- Use manganese rail-type drills of M-34 high speed steel with a slow spiral point and a compound point angle.
- Use standard reamers of M-1, M-2, or M-7 high speed steel.
- Use end mills of M-1 or M-3 Type 2 high speed steel with a fast spiral (32 deg standard) and minimum corner radius.
- Use mill cutters with a standard rake angle and made from M-1, M-2, or M-3 to get longer tool life.
- Use C-8 carbide-tipped flycutters.
- Use standard four-fluted taps of M-1 or M-2 with a flat crest relief and 10½ deg lead for plug taps and 30½ deg lead for bottom taps.
- All high speed tools should have liquid nitride or steam homo-surface treatment.
- Water-soluble oil mixed at 20-25 to 1 is best for all operations except tapping, for which you should use a good grade of cutting oil.—End

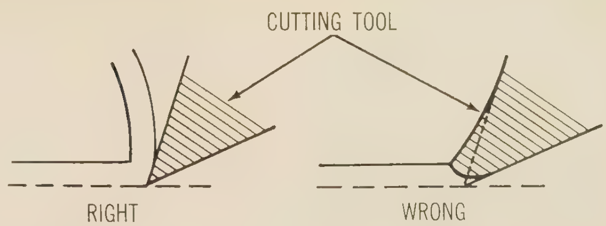
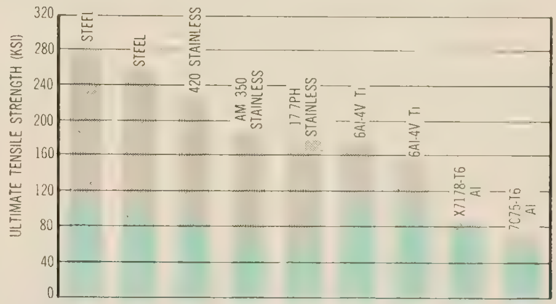
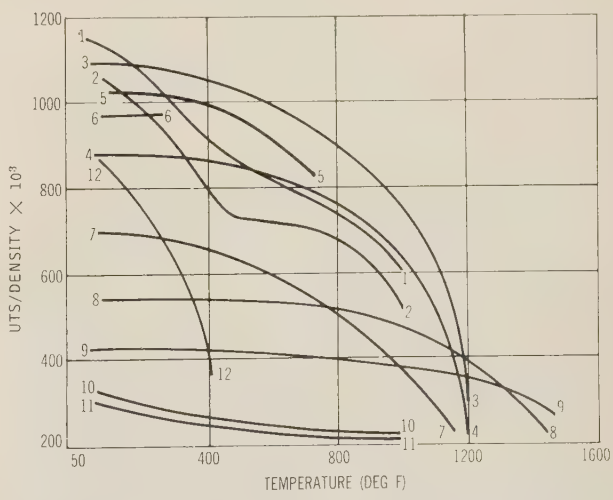


FIGURE 4: For any cutting operation, there is a theoretical optimum depth of cut. If the tool is up to too high a level, its tip deforms, and the tool tends to ride up and slide over without cutting.



ROOM-TEMPERATURE mechanical properties of several high strength materials.



COMPARISON of strength-density ratio's change with temperature for new high strength materials (curves 1-11) and aluminum (curve 12) in bar form. Alloys shown and their ultimate tensile strengths (UTS) in ksi at 70 deg F are: (1) titanium alloy, 180; (2) 6Al-4V titanium, 150; (3) Thermold J, 300; (4) Halcomb 218, 240; (5) Tricent, 290; (6) 4340, 270; (7) 17-4PH, 195; (8) Inconel X; 160; (9) S-816, 130; (10) 347 Cres, 91; (11) 301 Cres, 85; (12) 7178 aluminum, 86.

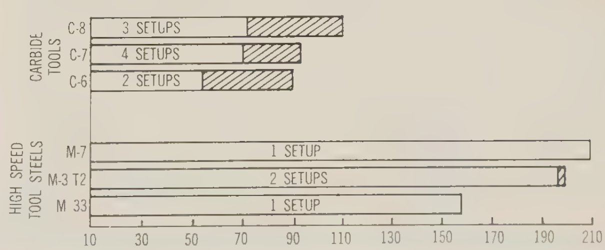


FIGURE 5: Efficiency studies are helping production engineers to make the best use of current cutting tools. This graph compares carbide and high speed tool steel as the cutter material for producing a 56-R_c 4340 steel part at 30 sfm. The feed equals the chip load of 0.0005 in.; the stop point is 0.003-0.005 in wearland or edge failure; and the cutter is a face-mill type with inserted blades.

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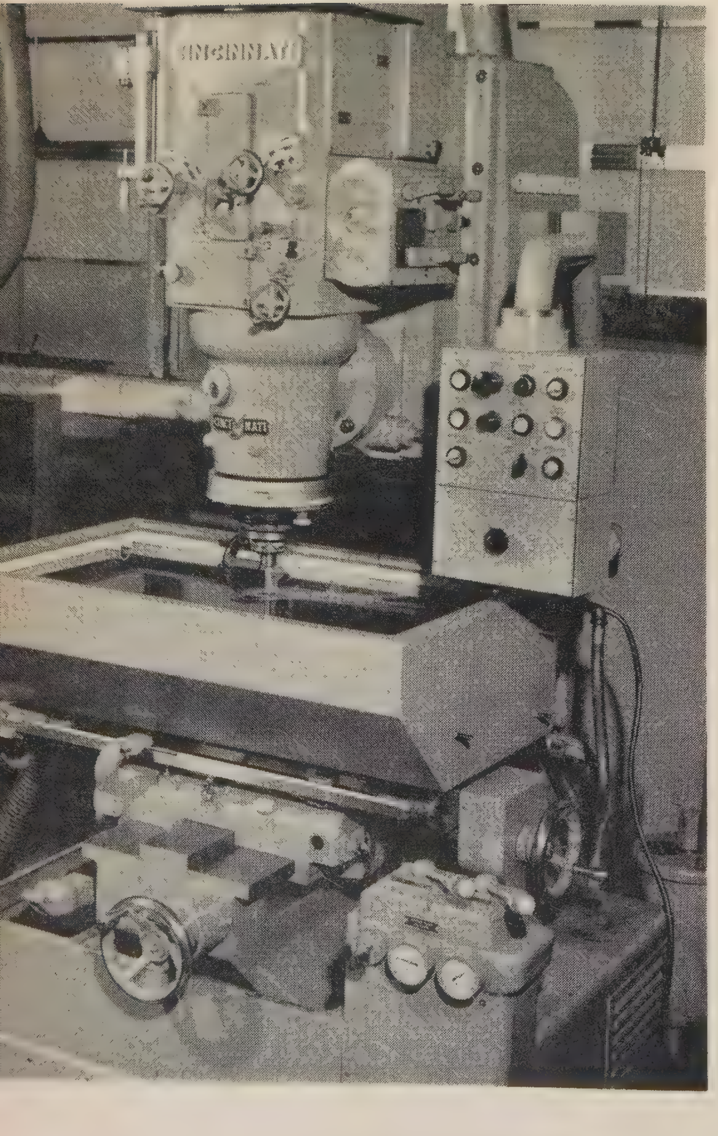
Chipless methods

for machining high temperature metals



- Chemical milling in development for titanium and new alloys
- "Fast" electric-discharge machines designed in Russia

by Alfred G. Jones, Design Producibility Engineer, North American Aviation, Inc.*

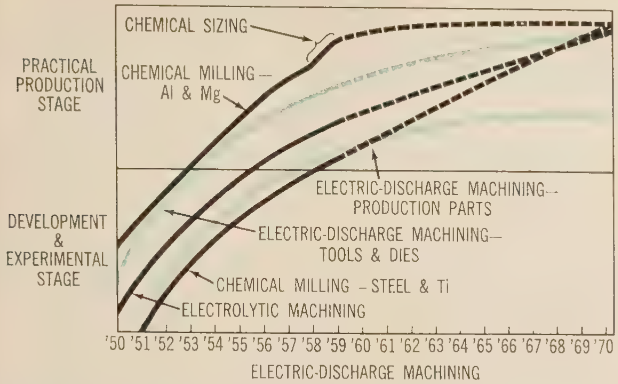
MOST OF THE NEW high strength, heat-resistant alloys practically defy conventional machining (in which you cut or chip away unwanted material). Luckily, these alloys can be machined by "chipless" techniques.

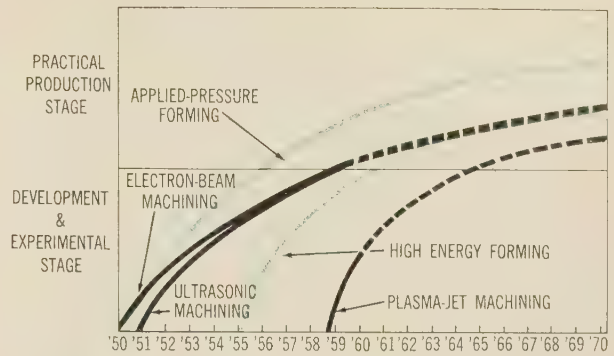
These techniques include chemical milling, electrolytic, electric-discharge, electron-beam, ultrasonic, and plasma-jet machining, and the material-displacement method. Only the last process is truly "chipless". In the other methods, material is actually removed from the workpiece—not as chips, though, but in the form of powder or granules or in solution.

Chemical milling is used on stainless steels, heat-resistant high strength alloys, and titanium both for machining and for sizing sheet and plate to thickness dimensions. Most of the time, though, the Chem-Mill process (developed by NAA) is considered a method

*North American Aviation, Inc., International Airport, Los Angeles 45, Calif.

◀ **ELECTRIC-DISCHARGE MACHINING** is automatic once the part is set up and the machine put in operation. Where the electrode enters the oil bath a wisp of smoke is generated by the machining process. This Cincinnati Milling Machine Elektrojet unit has a movable work table and a universal work head that can impart vertical, angular, rotational, and planetary motions to the electrode.





GROWTH TRENDS for chipless machining methods. Applied-pressure and high energy forming both use material displacement and are actually the only ones among these processes that are literally "chipless".

for detailing airframe skins. More than one surface of a skin or part can be chemically milled at one time, and several different parts can be processed concurrently.

The final dimensional tolerances usually depend on the material's initial tolerance and the depth of the etch (i.e., of the material that is removed). Closer tolerances than those listed in the *Table* can be held by mechanically or chemically sizing the sheet or part to a close tolerance before chemical milling. This procedure, of course, increases costs.

Of the newer materials used in Mach 3 vehicles, perhaps the most difficult to process by chemical milling are the high-nickel and the titanium alloys. The corrosion-resistant nickel alloys are not readily attacked by the standard etchant solution used for steel. They require a special chemical bath as well as especially close control during milling. Chemical milling of welded joints in high-nickel alloy is virtually impossible.

With titanium, the big problem is the tendency of titanium alloys to pick up hydrogen during chemical milling. The resulting embrittlement makes the alloys useless for airframe applications.

In summary we can say that chemical milling is a well-established production technique for aluminum and magnesium and is in its early stages as a reliable production method for stainless. For titanium and the newer high strength heat-resistant, alloys, it has not yet emerged fully from the experimental lab stage.

Electrolytic machining is an efficient and practical way of machining stainless steel honeycomb cores (flat, tapered, or contoured) to close tolerances. This technique can be thought of as highly accelerated electroplating in reverse or as a combination of fast etching and lapping.

In a typical setup, the workpiece becomes the anode and a special "grinding" wheel serves as the cathode. A gap of about 0.001 in. is held between wheel and workpiece, and the material is "machined" without contact. A constant flow of coolant washes away the material as it is removed.

A wheel of free-machining brass, slotted and filled with abrasive epoxy resin containing aluminum oxide, works very well. Usually, a cup-type wheel on a vertical spindle is used if the core is to be machined flat or to a single, constant taper. A horizontal spindle setup is used in contouring or step-cutting. Machining speeds for steel honeycomb core can go up to 7500-7600 sfm (which is equivalent to using an eight-inch-diameter wheel at 3600 rpm).

A recent adaptation of this technique, based on the principle of spark erosion rather than on reverse plating, is said to be 30 times faster. The action of hundreds of electric arc contacts per second "boils" away the material. Because of the burning or melting action, there is danger of heat damage to the honeycomb core, even though water and electrolyte coolants are used.

This is a serious drawback, for metallurgical properties can deteriorate as a result of localized heating, particularly in the case of stainless honeycomb. For fast roughing-cuts, however, the "interrupted" arc approach may turn out to be valuable.

To produce the interrupted arc, a metallic wheel with open slots around its working face is used. The slots act as arc-breakers while the wheel revolves. No abrasive is used.

Extension of electrolytic method

Development work is still underway on extending the use of the standard electrolytic machining process to solid materials. If it succeeds, an important advance will have been made. A lot of the finishing for the B-70, for instance, must be done after heat-treating. This means that some materials, like the H-11 alloys, will be as hard as R_C 56-58, which will make them extremely difficult to machine by conventional chipping methods.

Electric-discharge machining, long used to overcome the almost impossible machining problems of the tool and die trade, has been picked up by the aerospace industry to produce parts for some of our newest aircraft and missiles. For instance, this technique is used to sink contour shapes into steel honeycomb, to finish deep pockets in hard materials after rough machining, to reduce fillet and corner radii in machined parts to

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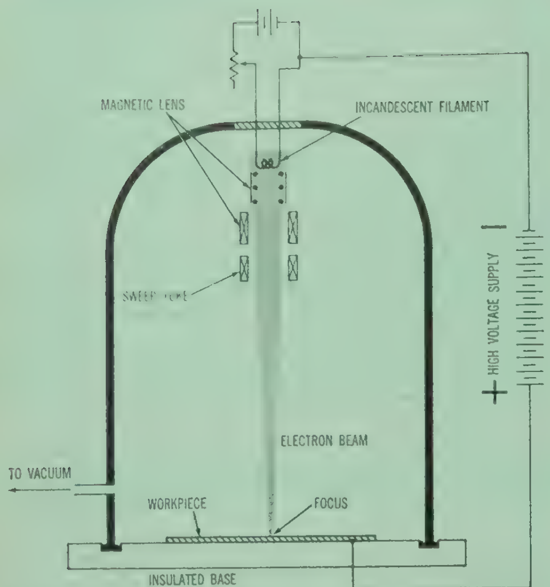


ELECTRON-BEAM machining is done in a vacuum. The magnetic lens system (whose connections are not shown) focuses the electron beam on the workpiece target. It is followed by a yoke controlling the sweep of the beam.

to reduce fillet and corner radii in machined parts to save weight, and to "drill" holes in heat-treated parts.

The limitations of electric-discharge machining lie in an inherently low material-removal rate (about 1.2 cu in./hr for standard machines) and in the need for machining with the workpiece submerged in a tank of dielectric liquid. Development programs are underway that are aimed at raising the material-removal rate.

Japan and Russia both have introduced "fast" electric-discharge machines powered by impulse generators. One Soviet model, operating on 28 kw, reportedly removes up to 20 cu in./hr of material. Using graphite electrodes for roughing and brass for finishing, it is said to sink a 5x5-in. cavity. A Japanese company claims to have a machine with an electrode of about 4x6 ft.

Because of the nature of the spark erosion process, any increase in the electric impulse (to speed up material removal) results in looser tolerances and a rougher surface finish. A combination of the standard electric-discharge machining and the new "fast" method could be a nice compromise.

One of the most recent techniques of chipless machining in the aerospace industry is electron-beam bombardment. As the schematic shows, the electron beam is focused on the workpiece inside a vacuum dome. The concentrated electrons produce temperatures as high as 10,000 deg C at the workpiece, causing instant vaporization of the material.

The beam diameter at the focal point can be made small enough to "drill" a hole only 0.0004 in. in diameter. Holes and slots ranging from 0.001 to 0.005 in. in size, with precise tolerance control and surface finishes as fine as RMS 4, are quite practical to produce.

Of course, there are again limitations. The need for a vacuum tends to restrict the size of the part, and the depth of penetration with accuracy is no more than ¼ in. Continued development, it is hoped, will make the electron-beam technique feasible for atmospheric operation.

Electron-beam units operate on high voltage but relatively low wattage (250-400 W), using special dc equipment to produce a pulsating action. Pulsating the beam keeps the highly concentrated heat from dwelling long enough to spread more than about 10 per cent of the whole diameter or slot width. (Most of the heat is removed by the vaporized material.) Tape control attachments can be used to operate the machine and cut intricate shapes and patterns.

The process can be used on almost any kind of material—zirconium, tungsten, molybdenum, aluminum oxide, the carbides, all high strength, heat-resistant alloys, etc. It is a proven method for intricate and extremely difficult work in highly specialized applications.

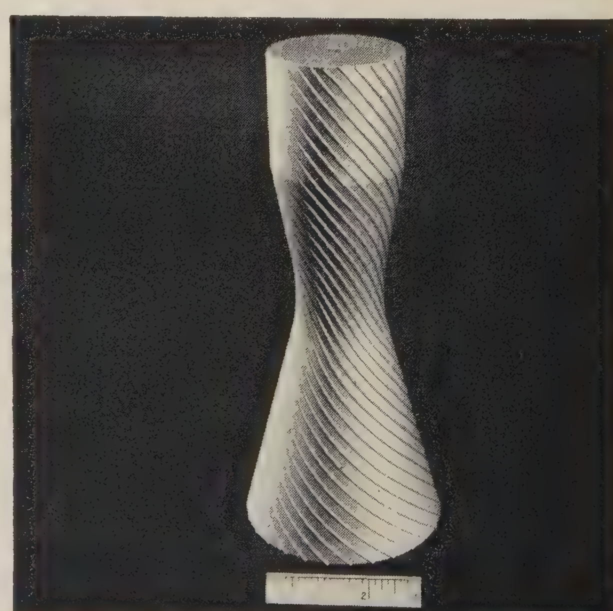
Still limited to small, fine work

Ultrasonic machining is similar to electron-beam machining in the intricate and miniature work it is used for and is also suited to the hard, "unmachinable" materials. A concentrated stream of an abrasive liquid mixture is directed against the workpiece at ultrasonic speed. This terrific bombardment, coupled with high frequency physical vibrations, makes possible precision drilling, slicing, broaching, trepanning, and shaping.

Like electron-beam machining, the ultrasonic-impact process is still limited to small, fine work in specialized fields, such as the manufacture of transistors, jewel bearings, and small extrusions and draw dies. Several types of machines are on the market, most of them single-spindle units. Russia claims to have an ultrasonic machine for doing extremely detailed work on hard but non-conductive materials.

Plasma-jet machining is akin to both the electron-beam and the ultrasonic techniques. The plasma-jet

UNUSUAL chem-milling pattern in an aluminum bar.



action is produced by a concentrated beam that raises the workpiece target temperature to 16,500 deg C, vaporizing the material. The beam consists of an arc of ions and electrons within a coolant wrapper that can be either liquid or gaseous. The coolant protects the material from heat damage.

Plasma-jet machining is still in the experimental stage. Practical applications are being explored, and within the next few years plasma-jet units may be in commercial use for specialized jobs.

Thread rolling is well established

The material-displacement techniques, which are truly chipless, include thread rolling, roll forming, spinning, and certain applications of high energy forming. Thread rolling is now a well established production method. Since no material is removed from the workpiece, the rolled threads are inherently stronger than machined ones. The displaced material is packed into the workpiece, which is why you end up with a stronger part (just as you do in forging bar stock).

Thread quality, dimensional accuracy, and surface finish are excellent if the correct rolling techniques are used. Since production rates are higher, too, no material is wasted, and tool preparation and maintenance take less time, thread rolling has become quite popular.

Roll-forming, a later but equally promising development, is used to produce gears and splined shafts without cutting or grinding. Essentially, the workpiece is subjected to a squeezing action under considerable pressure between two formed rollers or flat racks. The displaced material is partly compressed into the body of the workpiece and partly forced into the shape of the gear tooth or spline. This technique is particularly well suited for high strength parts and high production rates.

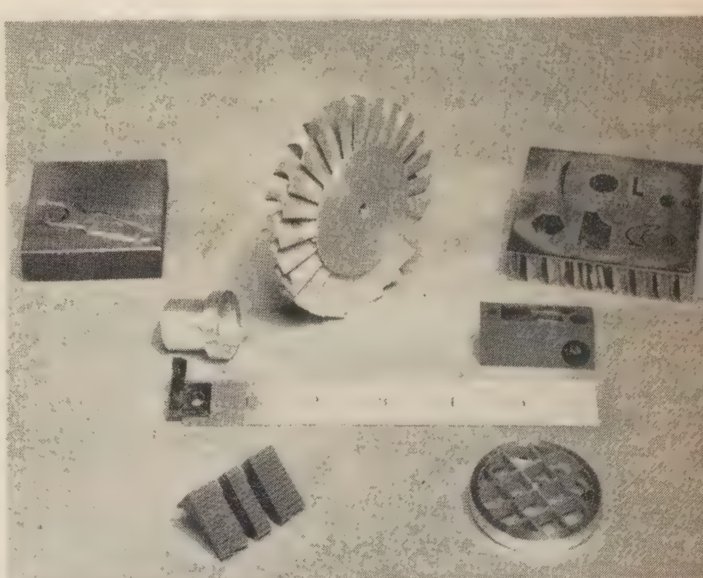
Spinning has been developed into a precise method for producing shaped parts for aircraft and missiles. Its basic principle is to "flow" material by pressure over a pattern. Exact contours and dimensions can be held with very little thinning of the material in sharply formed areas. Surface finishes as fine as RMS 6 pose no problem.

Several types of spinning machines have been introduced, some for horizontal and some for vertical operation. Various sizes are available, so that the part sizes that can be fabricated range from small, hand-size details to conical shapes for the largest missiles.

One of the newest techniques for producing "machined" parts without machining is high energy forming (see *"New Techniques, Greater Precision for Mechanical Forming," p. 85*). For instance, an explosive charge can be detonated to force material into shape. In another technique, the instantaneous release of high pneumatic pressure forces material into a precision die cavity or through a precision extrusion die. So great is the pressure, and so rapid the action, that the material is in a plastic condition as it is forced into the die shape. Intricate shapes, including gear teeth and serrations, can be produced in this way with almost any metal.—End

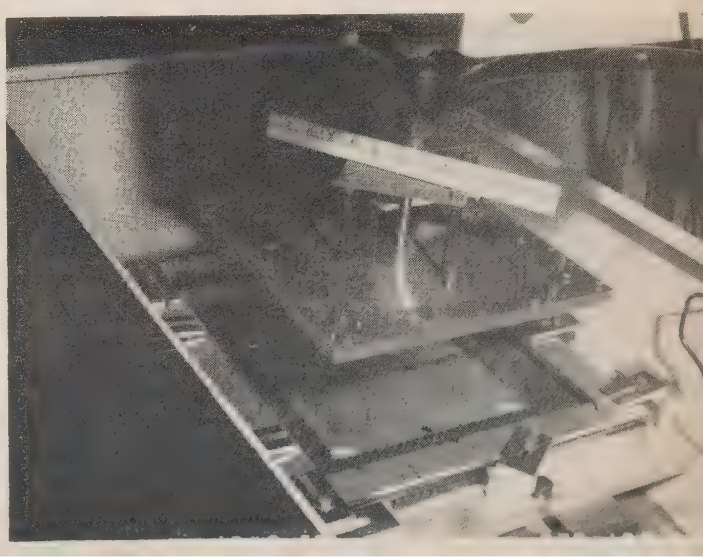
Removal Rates and Tolerances for Chemical Milling

	Depth of Etch per Minute (in.)	Total Depth of Cut (in.)	Milling Tolerance (in.)*
Aluminum	0.001	up to 0.020	±0.001
		0.021-0.060	±0.002
Magnesium	0.0013	up to 0.020	±0.001
		0.021-0.060	±0.002
		over 0.060	±0.003
Stainless steel & heat-resistant alloys	0.0005	up to 0.020	±0.001
		0.021-0.060	±0.002
		over 0.060	±0.003
Titanium alloys	0.0005	up to 0.020	±0.002
		0.021-0.060	±0.0035
		over 0.060	±0.005



TYPICAL WORK done on Cincinnati Milling Machine's electric-discharge units.

ELECTRIC-DISCHARGE machining is used to sink contour shapes, such as this rectangular one, into stainless steel honeycomb cores.



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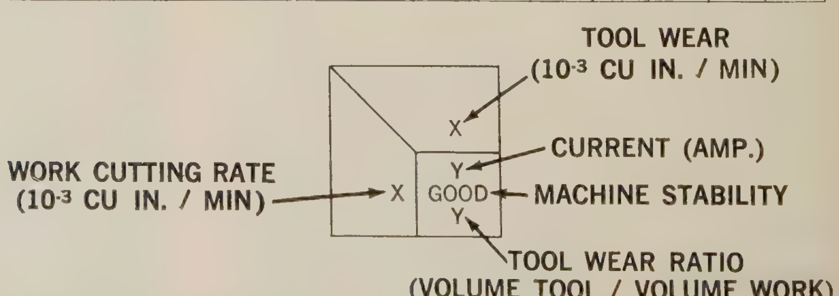
Electrode Materials for Discharge Machining

Prepared by
Robin O. Williams,
Milling Machine Div.,
Cincinnati Milling Machine Co.

TOOL MATERIAL (—)

WORK MATERIAL (+)	Zn	Mg	Pb	Cu	Al	Fe	Ti
Zn	8 / 15 / 12 GOOD 0.5	9.8 / 5.2 / 11 GOOD 1.9	8.6 / 5.4 / 10 FAIR 1.6	2.6 / 2.0 / 12 GOOD 1.3	6.7 / 5.2 / 12 GOOD 1.3	0.11 / 24 / 12 GOOD 0.005	0.28 / 12 / 12 GOOD 0.02
Mg	4.4 / 31 / 12 GOOD 0.14	6 / 13 / 8.5 GOOD 0.5	5.6 / 19 / 12 GOOD 0.3	0.28 / 19 / 10 GOOD 0.015	2.9 / 6.4 / 10 GOOD 0.5	0.2 / 3.8 / 9 FAIR 0.05	0.08 / 12 / 11 GOOD 0.007
Pb	5.4 / 11 / 12 GOOD 0.5	50 / 25 / 10 FAIR 2	3.2 / 2.8 / 8 POOR 1.1	0.58 / 13 / 10 GOOD 0.04	5.8 / 51 / 12 GOOD 0.11	0.44 / 7.4 / 10 POOR 0.06	0.19 / 0.66 / 2 POOR 0.3
Cu	4.6 / 5.6 / 14 GOOD 0.8	21 / 0.84 / 12 GOOD 25	15 / 1.4 / 10 FAIR 11	0.12 / 0.39 / 8 POOR 0.3	14 / 0.88 / 12 GOOD 16	2.6 / 2.0 / 12 GOOD 1.3	2.1 / 0.12 / 10 FAIR 17
Al	5.2 / 24 / 12 GOOD 0.2	7.2 / 6.1 / 11 GOOD 1.2	7.5 / 5.3 / 10 FAIR 1.4	0.29 / 9.3 / 12 GOOD 0.03	0.17 / 0.28 / 2 POOR 0.6	0.36 / 0.80 / 7.5 POOR 0.4	0.07 / 2.4 / 8 FAIR 0.03
Fe	11 / 0.63 / 12 GOOD 17	13 / 0.41 / 11 GOOD 30	14 / 0.80 / 12 FAIR 18	0.50 / 0.95 / 12 FAIR 0.5	0.91 / 0.53 / 8 FAIR 1.7	0.51 / 0.20 / 8 POOR 2.5	0.75 / 0.30 / 10 FAIR 2.5
Ti	9.2 / 3.8 / 14 GOOD 2.5	12 / 0.24 / 12 GOOD 50	0.04 / 0.40 / 8 POOR 0.1	0.36 / 2.8 / 10 POOR 0.13	1.2 / 0.16 / 10 FAIR 8	0.7 / 0.12 / 12 FAIR 6	0.06 / 0.03 / 2 POOR 2



Melting Points of Elements and Compounds (deg C)

Prepared by Servomechanisms Research Laboratory, Servomechanisms, Inc.

Elements		Oxides		Carbides		Nitrides		Borides		Sulfides[1]		Compounds and Natural Crystals	
Carbon (C)	3652	ThO_2	3300	4TaC:1HfC	3942	HfN	3310	HfB_2	3062	CeS	2450	Diamond (C)	3500
Tungsten (W)	3410	MgO	2800	4TaC:1ZrC	3932	ZrN	2980	ZrB_2	3060	ThS	>2200	Thorium Zirconate ($ThO_2 \cdot ZrO_2$)	>2800
Tantalum (Ta)	3027	HfO_2	2777	HfC	3887	TaN	2980	TaB_2	3000	Hfs	2100-2200		
Osmium (Os)	2700	ZrO_2	2677	TaC	3877	TiN	2950	WB	2920	ZeS	2050-2150	Zircon ($ZrSiO_4$)	2420
Molybdenum (Mo)	2625	CeO_2	2600	ZrC	3530	BN	2730[2]	TiB_2	2900	BaS	>2000	Calcium Zirconate ($CaO \cdot ZrO_2$)	2345
Iridium (Ir)	2454	CaO	2600	NbC	3500	ScN	2650	ThB_4	>2500	MgS	>2000	Tungsten Silicide (WSi_2)	2180
Niobium (Nb)	2415	BeO	2550	Ta_2C	3400	UN	2630	B_4C	2450	SrS	>2000	Spiel ($MgO \cdot Al_2O_3$)	2135
Boron (B)	2300	SrO	2415	TiC	3140	ThN	2360	UB_4	<2400	US	<2000	Sapphire (Al_2O_3)	2050
Hafnium (Hf)	2110	Cr_2O_3	2265	WC	2867	AlN	2230	UB_2	2360	TiS	2000-2100	Molybdenum Silicide ($MoSi_2$)	2030
Rhodium (Rh)	1996	Ti_2O_3	2130	W_2C (beta)	2857	$\frac{1}{2}Be_3N_2$	2200	MoB	2180	ThS_2	1905	Peroyskite ($CaO \cdot TiO_2$	1975
Chromium (Cr)	1890	Al_2O_3	2015	VC	2830	VN	2030	ThB_6	>2100	PbS	1114	Aluminum Titanat ($Al_2O_3 \cdot TiO_2$)	1895
Zorconium (Zr)	1830	V_2O_3	1977	MoC	2692	NbN	2030	VB_2	2100	Al_2S_3	1100	Crysoberyl ($BeO \cdot Al_2O_3$)	1870
Thorium (Th)	1827	BaO	1917	Mo_2C	2687	$\frac{1}{4}Si_3N_4$	1900[2]	Mo_3B_2	2070			Mullite ($2Al_2O_3 \cdot 2SiO_2$)	1830
Platinum (Pt)	1774	Ta_2O_5	1890	ThC_2	2655	CrN	1770	NbB	>2000			Beryllium Titanate ($2BeO \cdot TiO_2$)	1800
Vanadium (V)	1735	TiO_2	1840	ThC	2625			TaB	>2000			Magnesioferrite ($MgFe_2O_4$)	1760
Titanium (Ti)	1725	CoO	1805	SiC	2600[2]			MoB_2	2000			Titanium Silicide ($TiSi_2$)	1540
Palladium (Pd)	1549	TiO	1750	B_4C	2450			CrB_2	1850			Zirconium Silicide ($ZrSi_2$)	1520
Iron (Fe)	1535	SiO_2	1728	UC_2	2350			FeB	1550[3]			Beryl ($Be_3Al_2Si_6O_{18}$)	1410
Cobalt (Co)	1495	Li_2O	1700	UC	2250			Fe_2B	1389				
Nickel (Ni)	1455	Fe_2O_3	1565	Be_2C	2100[4]			Ni_2B	1230[3]				
Silicon (Si)	1420	Fe_3O_4	1538	Cr_3C_2	1890			Ni_3B_2	1170[3]				
Beryllium (Be)	1278	WO_3	1473	U_2C_3	1800[4]			AlB_2	1100[3]				
Copper (Cu)	1083	FeO	1420	Cr_7C_3	1665			CrB	1038[3]				
Gold (Au)	1063	CuO	1026	Fe_3C	1650			NiB	1020				
Silver (Aq)	961			$Cr_{23}C_6$	1550								
Germanium (Ge)	959			Mn_3C	1520								
Barium (Ba)	850			Al_4C_3	1400								
Calcium (Ca)	842												
Strontium (Sr)	757												
Aluminum (Al)	660												
Magnesium (Mg)	651												
Antimony (Sb)	631												
Arsenic (As)	615[2]												
Tellurium (Te)	452												
Zinc (Zn)	419												
Lead (Pb)	327												
Cadimum (Cd)	321												
Bismuth (Bi)	271												
Tin (Sn)	232												
Selenium (Se)	217												

(1) Stoichiometric sulfides are not listed. (2) Sublimation temperature. (3) Approximate. (4) Decomposition temperature.

Recommended Welding Processes

From "ARDC Production Design Handbook"

	Low-C Mild Steel	Medium-C Steel	Wrought Alloy Eng. Steels	High Alloy Stainless Steels, Austenitic	Stainless Steels, Ferritic & Martensitic	High Temperature Alloys	Cast Fe, Gray Fe	Al, Al Alloys	Ni, Ni Alloys	Cu, Cu Alloys	Mg, Mg Alloys	Ag	Au, Pt, Ir	Ti, Ti Alloys	U, Mo, V, Zr, W
Shielded Metal Arc (coated electrode)	R	R	R	R	R	R	S	S	R	NR	NA	NR	NR	NA	NA
Submerged Arc	R	R	R	R	S	S	S	NR	S	NR	NA	NR	NR	NA	NA
Atomic H	S	S	S	R	S	SS	NR	S	S	NR	NR	R	R	NA	NR
Inert-Gas W Arc	S	S	S	R	S	S	S	R	R	R	R	R	R	R	R
Inert-Gas Metal Arc	S	S	S	R	S	S	NR	R	R	R	S	S	S	S	S
Flash	R	R	R	R	S	S	NR	S	S	S	NR	S	S	S	S
Spot	R	R	R	R	S	S	NA	R	R	S	S	NR	S	S	S
Gas (oxy-acetylene)	R	R	S	S	S	S	R	S	S	S	NR	R	R	NA	NR
Thermit	S	S	S	NR	NR	NR	S	NA	NR	NR	NA	NR	NR	NA	NR

S—Satisfactory, R—Recommended, NR—Not Recommended, NA—Not Applicable

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5

Production know-how gaining on superalloys and refractory metals

- Heat-resistant metals produced with uniform properties
- Popular superalloys available from many suppliers

by R. H. Sparling, Design Specialist,
Convair-Pomona*

THE THREE MAJOR problems of heat-resistant metals for aerospace vehicles—lack of uniformity, limited supply, and difficult fabrication—largely have been overcome.

The use of strong, stiff, or heavy metals necessarily poses some problems. It is not enough to make René 41 or molybdenum parts to the dimensional tolerances used on magnesium or aluminum parts. The heat-resistant metals are so much heavier (*Fig. 2*) that an extra 0.001 in. on a part unquestionably represents a significant weight increase. Thin skins and precise machining are basic requirements.

The superalloys are generally used to about 1700 deg F and the refractory metals at higher temperatures. Superalloys (*Table III*) fall into three classes:

- Complex Ni-Fe-Cr alloys with or without cobalt are cheapest to fabricate.
- Nickel-base alloys are strongest in the 1200-1600-deg-F range but harder to handle in the shop.
- Cobalt-base alloys have especially good oxidation resistance above 1600 deg F.

Most of the high strength alloys are precipitation-hardening (PH) types and usually contain some aluminum and titanium. Yield strengths above 100,000 psi at 1500 deg F are not uncommon. The relative positions of the various alloys in *Figure 3* may be changed by differences in heat-treat, test conditions, or cold-work.

If long exposure to high temperatures is expected,

* Convair Div., General Dynamics Corp., Pomona, Calif. The author wishes to acknowledge the help of Allegheny Ludlum Steel, Fansteel, General Electric, Haynes Stellite, International Nickel, Kelsey Hayes, Stanford Research Institute, Universal Cyclops Steel, and Westinghouse, Electric.

Table I: Effect of Cold-Work on Hastelloy R-235

Condition	Yield Strength (ksi)	Ultimate Tensile Strength (ksi)	Elongation (percent)	Erichsen Cup (mm)	Bend Radius
Mill-annealed	122	175	45-50	10-12	½ T
Cold-worked					
10 per cent	150	180	22-36	7-9	2 T
20 per cent	155	190	14-20	6½-7¾	¾ T

Table II: Availability of Refractory Metals

	Co[1]	Mo[2]	Ta	Re	W
Bar	X	W	X		X
Rod	X	W	X	L	X
Sheet	X	W	W		
Strip	X	W	W	L	X
Tubing	X	W	X		
Wire	X	W	X	L	W

Code: X—Readily available, W—warehouse, L—lab amounts.
(1) Including F-80 and F-82 alloys. (2) Including 0.5Ti alloy.

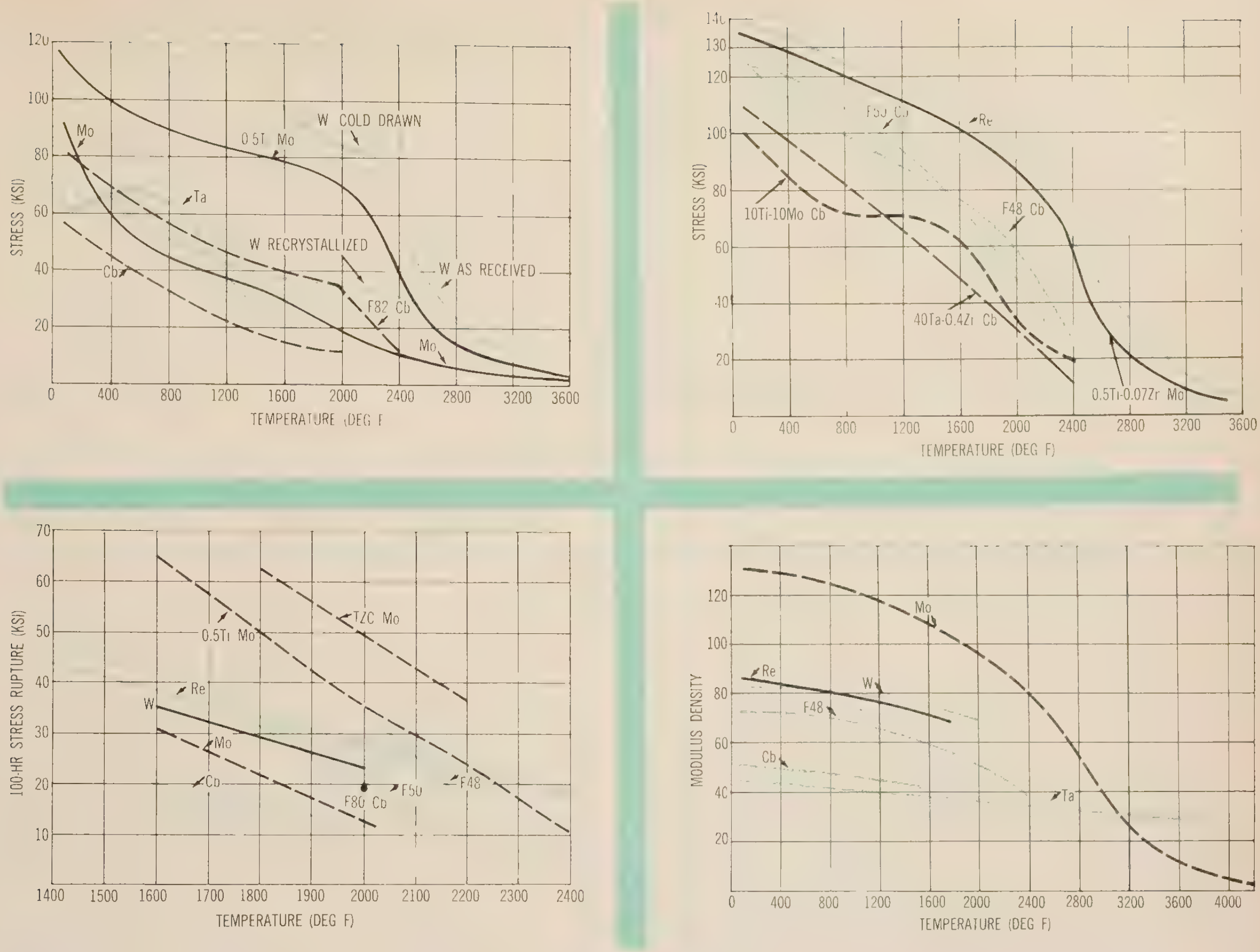


FIGURE 1: Tensile strengths of production and experimental refractory metals (top) and 100-hr rupture strength of refractory metals. Bottom right: Modulus-density ratio of superalloys vs temperature.

creep and therefore rupture strength are of paramount importance. As *Figure 4* shows, nickel-base castings are superior at the higher temperatures.

The machining practice for superalloys is similar to that for the 18-8 stainless steels, except that more power is needed. Since these metals work-harden rapidly, the machining equipment must be very rigid —it must be over-powered as much as possible. Tools must be sharpened and indexed frequently. Feeds and speeds must be lower than for conventional aircraft metals and cuts heavier.

Complex Fe-alloys easiest to handle

In general, the complex iron-base alloys, like A-286 and Discaloy, are easiest to handle and the nickel- and cobalt-base ones more difficult (*Table IV*). Nevertheless Hyanes-Stellite recently listed over 350 fabricators with experience on nickel- and cobalt-base alloys. Alloy producers, incidentally, can supply much data on tool materials and design, cutting fluids, and recommended machining practices.

Sometimes chem-milling is better than machining. For Inconel X, for instance, it gives a removal rate of about 0.001 ipm, with tolerances of roughly 0.002 in. over the original dimensions.

Though the superalloys resist deformation in the forging temperature range because of their high strength, most of them are actually being forged into quite intricate shapes. The iron-base alloys are easiest to forge, and next come the Fe-Ni-base types like D-979. The nickel- and cobalt-base alloys are more difficult. Still, complex die forgings such as turbine wheels with integral blades are common production items in these latter alloys.

Most superalloy compositions can be obtained as investment castings.

Cold-forming goes amazingly well when these alloys are in the annealed or solution-treated condition. Discaloy bolts are cold-headed and the threads cold-rolled. Inconel X parts for the X-15 airframe include flanged and formed corrugations, spun bulkheads, beaded and chem-milled panels, power-formed ogives, and hydroformed cones.

Cold-forming takes plenty of power, and most of the higher strength alloys require intermediate anneals, since they work-harden so quickly. The cold-working is a great asset for short-time exposure to heat, for many superalloys get their maximum strength from a combination of cold-work and heat-treat.

Cold-working does reduce ductility and therefore

more on next page

Table III: Availability of Superalloys

	Mill Products			Forgings		Investment		
	Bar	Sheet	Wire	Hand	Die	Impact	Cast-ings	Exru-sions
A-286	X	X	X	X	X	X	X	X
Discaloy	X	X			X			X
W 545	X	X			X			
N-155	M	M	W*	X	X			
Incoloy 901	W	W	W			X		X
D 979	X	X	X	X	X	X	X	X
Inconel X	W	W	W			X		
GMR 235							X	
Inco 713C							X	
Hastelloy X	M	M	M	X		X	X	X
R-235	M	M	M	X			X	X
AF-1753	X	X	X	X	X			
René 41	M	W*	M	X	X	X	X	
M-252	X	X	X	X	X	X	X	X
Waspaloy	W*	W*	X	X	X		X	
Udimet 500	W*	W*		X	X		X	
Udimet 600	X			X	X			
Nicrotung							X	
inconel 700	W							
L-605	M	M	M	X		X	X	X
J-1570	X	X		X	X	X	X	
V-36		X						
S-816	X			X	X			
Refractoloy 80	X	X		X	X		X	

X—available, M—mill stock, W—warehouse. Asterisk indicates limited amount.

Table IV: Machinability of Superalloys

	Condi-tion	Turn-ing	Grind-ing	Drill-ing	Ream-ing	Chemical Milling
A-286	ST & A	fair	fair	fair	fair	fair
Discaloy	ST & A	fair	fair	fair	fair	fair
W-545	ST & A	fair	fair	fair	fair	fair
N-155	ST	fair to good	good	fair	fair	good
Incoloy 901	ST	fair	good	fair	poor	good
D-979	ST & A	fair	fair	fair	fair	fair
Inconel X	ST	fair	good	fair	poor	fair
GMR 235	as cast					
Inco 713C	as cast					
Hastelloy X	annealed	good	good	good	good	good
R-235	annealed	good	good	fair	fair	good
AF-1753	ST & A	poor	fair	poor*	poor*	
Rene 41	ST & A	fair	fair	fair*	fair*	good
M-252	ST	poor	fair	fair	poor	
Waspaloy	ST	fair	good	good	poor	good
Udimet 500	ST or STA	fair	good	fair	poor	fair
Nicrotung	as cast		fair			
Inconel 700	ST	fair	good	fair	poor	
L-605	annealed	good	good	fair	fair	good
J-1570	ST & A	fair	fair	poor	very poor	
S-816	ST & A	poor	fair	poor	very poor	
Refractoloy 80	ST & A	poor	fair	poor	poor	

*After solution treatment.

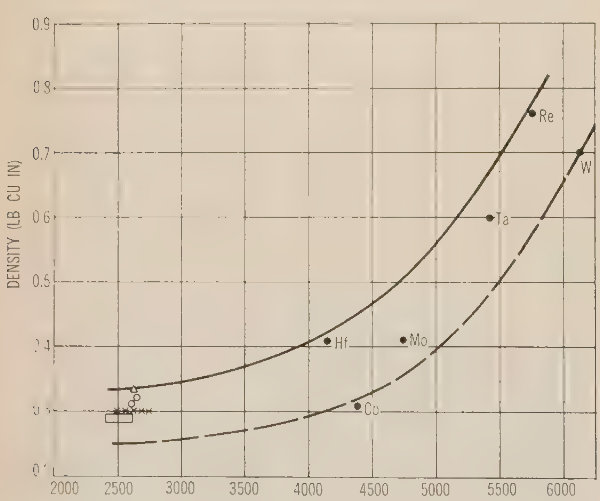


FIGURE 2: Density of heat-resistant metals. Rectangle at lower end of the curves indicates values for A-286, Discaloy, W-545, U-600 and -500, Inconel 700, D-979, R-235, Waspaloy, René 41, M-252, and Hastelloy; cross-hatching indicates values for N-155, Inconel X, V-36, J-1570, AF-1753, and Nicrotung; open circles indicate values for S-816 and Refractaloy 80; and the triangle indicates the value for L-605.

fabricability (*Table I*). But simple forming can be done on cold-worked alloys if you are careful. Sometimes the forming operation itself contributes to increased strength.

Table V shows typical heat-treat cycles for some of the PH alloys. One of the best things about the superalloys is that their properties can be varied extensively by heat treatment, which helps you to get maximum strengths for specific applications. For instance, the maximum short-time strength of René 41 is achieved by 1950-deg F solution treatment and a 16-hr, 1400-deg F age. But if long-time service is needed, higher stress-rupture values are obtained by solution treatment at 2150 deg F and aging at 1650 deg F for four hours. Manufacturers can suggest optimum heat-treat cycles for different service conditions.

For stress-relieving and annealing, nickel-base alloys should be heated through the 1200-1400-deg F range as quickly as possible. Otherwise they may age before the stress relief is achieved.

Since nickel-base metals are more susceptible to sulfur embrittlement than steels, they should be cleaned very carefully before heat treatment. Alloys like HS respond well to sodium hydride baths.

Welding of PH alloys is standard practice today. All the common fusion and resistance welding methods, except for the submerged-arc technique are being used successfully on the superalloys. Welding is always done on fully annealed or solution-treated

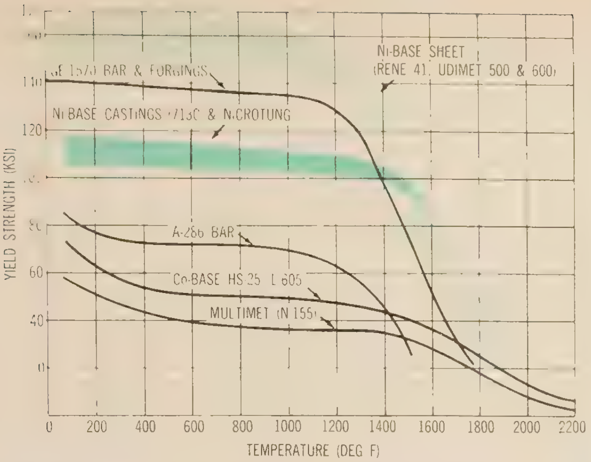


FIGURE 3: Yield strengths of some superalloys at 0.2 per cent offset.

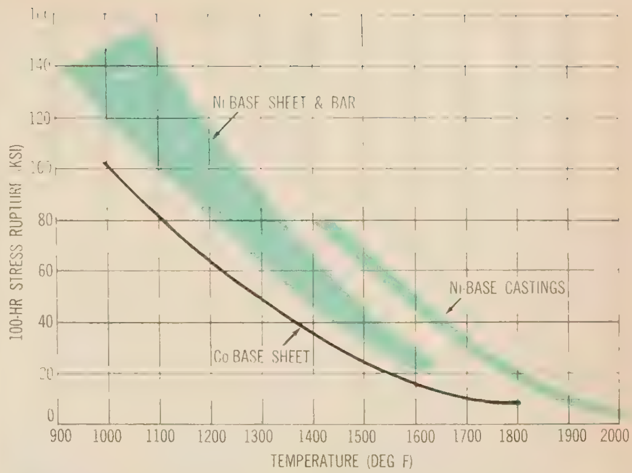


FIGURE 4: Hundred-hour rupture strength of superalloys.

material with good alignment, a minimum of restraint, and a lot of power.

Welded parts are formed, spun, and flanged without trouble. The welded Inconel X tank for the X-15 was spun to final size; problems with cracks in the weld area that developed during spinning were solved by preparatory precision-milling and roll-planishing of the welds.

One of the newer applications of welded structure is the resistance-welded sandwich. HS-25 (L-605) sandwich is being tested for the Talos nose.

Brazing is harder to do on PH metals—the aluminum and titanium oxides that form on the surface keep the braze from wetting the base metal. A Ni-Cr-B braze in an extremely dry hydrogen atmosphere or a vacuum, however, gives excellent results. Also, the surface can be given a thin plating of nickel before brazing. Alloys like Hastelloy X, N-155, and HS-25, which suffer no Ti-Al hardening, are readily brazed without these precautions.

In fact, all the usual hot- and cold-forming, machining, and joining processes used on conventional aircraft metals are also being applied to superalloys. The latter require more power and care, but the results are equally good.

Refractories are coming forward

The high-melting-point, or refractory, metals are coming forward very fast as aerospace structural materials (*Tables II& VI*). Two drawbacks—poor oxidation resistance and difficult fabrication—are being combated by work on protective coatings, new alloys, advanced processing methods. Major recent developments include molybdenum castings, highly ductile molybdenum sheet, stronger columbium alloys, and the high speed fabrication of tungsten and new tantalum alloys.

Because of their high melting points, most refractory metals are prepared by powder metallurgy. Molybdenum, of course, can be arc-cast. (There are often significant differences in the properties of arc-cast and powder-metallurgy molybdenum.)

Molybdenum, especially as the 0.5Ti alloy, is the most widely used refractory metal. Tantalum and columbium, both soft, ductile, and easily worked, are becoming increasingly popular. Tungsten is just coming into the picture as a structural metal, while rhenium is still a lab product.

Several values in *Table VI* are of peculiar importance for refractory metals. For instance, it's essential that you know the recrystallization temperature (which is affected by size and previous working) and don't exceed it in processing. All these metals gain strength through working and strain-hardening, rather than through heat treatment. The added strength is lost at temperatures above the recrystallization temperature. Also, the metal in the recrystallized state is much weaker, even at room temperature, than the worked material.

Oxidation at high temperature is a problem for the entire refractory group, but especially for molybdenum. Above 1500 deg F, this metal may oxidize, vaporize, and completely disappear in a short time. Rhenium has an even more volatile oxide and vaporizes at 700 deg F. Columbium is also subject to internal oxidation, which causes embrittlement.

Fortunately, a number of good coatings is commercially available. No single coating, though, meets all operating needs. Two of the most promising coatings are Chromalloy W-2, a cementation type, and Al-Si-Cr, which is sprayed on. Precious-metal and Ni-Cr plating are useful up to about 2000 deg F.

The bend transition temperature (*Table VI*) affects fabricability because below it refractory metals fracture in a brittle manner. Molybdenum and tungsten must be heated for fabrication and handled with care in the shop to avoid damage.

Table VII lists some currently available alloys. The 0.5Ti molybdenum alloys have high strength and higher recrystallization temperatures than the pure metal —2200-2450 deg F instead of 1800-2200. Many other compositions are still in the lab stage. In tungsten alloys, 30-50 per cent rhenium is said to lower the bend transition temperature and aid in working. There is also a 70Ta-30W alloy workable at room temperature.

more on next page

Table V: Heat Treatment of Typical PH Superalloys

	Anneal (hours at degrees F)	Solution Treat (hours at degrees F)	Aging (hours at degrees F)
Iron-Base Alloys			
Discaloy	2 @ 1850	2 @ 1850	20 @ 1350, 20 @ 1200
A-286	1 @ 1850	1 @ 1800	16 @ 1350
D-979	1 @ 1850	1 @ 1850	6 @ 1550, 16 @ 1300
Incoloy 901	2 @ 1850	2 @ 2050	24 @ 1375
Nickel-Base Alloys			
Inconel X	½ @ 1950	2 @ 2100	24 @ 1550, 20 @ 1300
Inconel 700	2 @ 2050	2 @ 2160	4 @ 1600
Incoloy 901 bar	2 @ 2050	2 @ 2050	24 @ 1375
Incoloy 901 sheet	⅙ @ 1950	⅙ @ 1950	2 @ 1400
Udimet 500	2 @ 2150	4 @ 1975	24 @ 1550, 16 @ 1400
Udimet 600	2 @ 2150	4 @ 1975	24 @ 1550, 16 @ 1400
M-252	4 @ 1950	4 @ 1950	15 @ 1400
R-235	1 @ 2150	1 @ 2000	¾ @ 1100 to 4 @ 1400, 1 @ 1400
René 41	½ @ 1975	⅙ @ 1950	16 @ 1400
Cobalt-Base Alloys			
S-816	1 @ 2150	1 @ 2150	16 @ 1400
J-1570	4 @ 2150	4 @ 2150	16 @ 1650
V-36	1 @ 2250	1 @ 2250	16 @ 1400
Refractology 901	2 @ 2050	2 @ 2050	24 @ 1375

Table VI: Refractory Metals

	Co	Mo	Ta	Re	W
Melting point (deg F)	4380	4750	5425	5755	6150
Density (lb/cu in.)	0.31	0.37	0.60	0.76	0.70
Thermal expansion at room temperature (deg F)	4.0	3.1	3.6	3.6	2.2
Nuclear cross-section (barns)	1.1	2.4	21.3	85.	19.2
Thermal conductivity (btu/hr/sq ft/ft/deg F)	30.5	72	32	?	83
Specific heat (btu/lb/deg F)	0.064	0.061	0.0356		0.034
Recrystallization temperature (deg F)	1650–2400	1800–2200	1925–2725	2550	2375–2725
Stress relief temperature (deg F)	1500–1950	1650–1800	1650–1950	2000*	1800–2200
Bend transition temperature (deg F)	−200	0–100	−200		300–700
Relative severity of oxidation	4	2	5	1	3
Oxide Volatilization temperature (deg F)	2500	1500	2500	700	1850
Fabricability	good	poor	good	poor	very poor
Fabrication temperature (deg F)	RT	400–2000	RT	RT	750–3000
Modulus (10^{-6} psi)	20	46	27	67	59
Strength (ksi)					
Annealed	50	55	67	165	100
Cold-worked	100	115	150	300	400
At 1800 deg F	17.5	29		85	36.5
Stress Rupture after 100 hr @ 1800 deg F (ksi)	15	22			28.5

*Annealed.

Figure 1 shows some mechanical properties for refractory metals. As manufacturers gain experience in alloying and treating these materials, higher strengths will be achieved. What can be done is shown, for instance, by the difference between pure columbium and the new experimental alloys.

Cb and Ta are hard to machine

Molybdenum is fairly easy to machine—like a steel at R_C 30 but with more abrasion. It requires rigid equipment, carbide tools, and plenty of coolant. Punching, stamping, or sawing are liable to split or crack it. It should be cut with an abrasive cutoff wheel flooded with coolant or heated to 400-1000 deg F for shearing.

Columbium and tantalum, on the other hand, are almost too ductile. They tend to flow and "gum up" when sawed or machined, and tantalum also galls badly. With sharp tools, shearing is no problem. Because of their low rate of work-hardening, these metals can be punched and stamped easily with no danger of springback.

Tungsten is very difficult to machine or saw. Grinding at low speed with continuous water cooling is about the best finishing method. Tungsten can be sheared, punched, and stamped if both tool and metal are hot (750-2000 deg F). Sheet 0.005-0.01 in thick may be sheared at 1100-1500 deg F, when the thickness increases to 0.125 in., the temperature must be raised to 2200 deg F.

It's usually better to forge, spin, or extrude all the refractory metals as closely as possible to the final desired dimensions, in view of the high cost of machining. These metals can all be hammer-, die-, and impact-forged. The forging of tungsten shapes is a new development, made possible by the use of high power and rapid working.

Casting methods for molybdenum have just been developed—too recently to evaluate the resulting strength properties. Casting to shape should eliminate many fabrication steps and reduce the cost of the finished parts. Tungsten is being slip-cast into nozzle shapes.

A unique new method is the spraying of metal power parts. Tungsten, tantalum, and molybdenum can be deposited on a mandrel, either to line another material or to form the entire part. The mandrel later is leached out. Good density and tolerances of ±0.002 in. are attained.

Columbium and tantalum are very ductile and easy to form, spin, twist, draw-bend, etc., at room temperature. Reductions of up to 90 per cent may be taken at room temperature without an intermediate anneal. Molybdenum presents a problem with its tendency to laminate or crack and its lack of ductility at room temperature. It must be moved hot (*Fig. 5*).

Temperatures used successfully on molybdenum are

(in degrees F): drawing, 250; spinning and hydrospinning, 600; stretch-wrapping, 1200; spinning at over 0.125 in. thickness, 1800. The metal should be stress-relieved before spinning.

New, highly ductile 0.125-in.-thick molybdenum sheets that can take 90-180-deg bends at room temperature without cracking have just been announced.

Important recent W breakthrough

Welcome recent news is that tungsten can be spun, deep-drawn, and die-formed if it is worked rapidly. Tungsten heats fast, because of its high thermal conductivity, but also quickly loses heat, because of its low specific heat. High rates of deformation and high temperatures make it possible to work tungsten into the desired shapes.

For die-forming, thin sheets and tools must be heated to 600-1100 deg F; blanks of over 0.1 in. must be at 2000 deg F or hotter. Deep-drawn parts up to 0.17 in. thick and spun sections of 0.125 in. are being made of tungsten.

The refractory metals cannot be strengthened by heat-treat, but they can be stress-relieved for fabricating. Because they tend to pick up gases at high temperatures, all work above 650-700 deg F should be done in a hydrogen or inert-gas atmosphere or in a vacuum. For tantalum, only extremely good vacuum equipment is satisfactory.

Cleaning these alloys is something of a problem. Molybdenum and tungsten may be cleaned in a molten-salt bath, sodium hydride, or chromic acid; columbium and tantalum are cleaned only by acid. Mechanical cleaning is best.

Molybdenum can be welded—the 0.5Ti alloy more successfully than the pure metal. A method for resistance welding is just being developed. Because of molybdenum's high electric and thermal conductivities, it requires extremely high power. With preheating, quick welding, postheating, and forging, spot welds with shear strengths of 900-1000 lb for 0.04-in. sheet and 1800-1900 lb for 0.056-in. sheet have been produced in the 0.5Ti alloy.

Fusion welding of molybdenum often produces brittle welds, laminations, or cracks. Up to 0.06 in. thickness, ductile welds can be obtained. Close control of preheat is necessary and, of course, complete protection from air—either weld in a chamber or use gas blankets.

Because of their reactions with gases, columbium and tantalum must be completely shielded. The former makes very ductile welds when shielded with very pure helium. The welding practice generally is very similar to that followed on titanium.

Tantalum can also be heliarc-welded, and resistance welds can be made under water if you take care not to use too much pressure. Tungsten can be resistance- and heliarc-welded.

Brazing is a long-established method for joining molybdenum to electronic components. Brazing alloys with copper, nickel, columbium, cobalt, platinum, palladium, and molybdenum bases are being evaluated for high temperature sandwiches. For 0.5Ti molybdenum, the palladium brazes appear most promising.

Satisfactory brazes are made by the oxy-acetylene torch and resistance processes as well as by induction and furnace methods. In all cases, careful cleaning and preparation are mandatory. A vacuum or a protective atmosphere is needed for high-melting brazes.

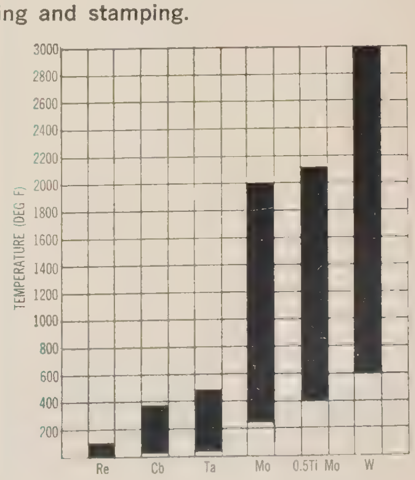
The requirements for brazing columbium and tantalum are similar to those of the welding processes for these metals.—End

Table VII: Analysis of Some Refractory-Metal Alloys

	Commercially Available	Al	Cb	Cu	Mo	Ni	Ta	Ti	V	W	Zr	Melting Point (deg F)	Density
Molybdenum*													
All	yes				bal.			0.5				4750	0.368
Climax	no				bal.			0.5			0.07		
Columbium													
du Pont	yes		bal.		10			10				4100	0.292
Fansteel F-80	yes		bal.								0.7	4350	0.311
Fansteel F-82	yes		bal.				33				0.7	4550	0.371
GE F-48	no		bal.		5					15	1	4500	0.33
GE F-50	no		bal.		5					15	1	4400	
H-S 1	no		bal.					5		10	5		
H-S 2	no	3	bal.						3				
Tantalum													
Temescal	yes						bal.			10			
Fansteel	no						bal.			30			
Fansteel	yes						bal.			7.5			
Tungsten													
Fansteel BL-2	yes					1				bal.			
Fansteel 77	yes			4		7				bal.			

*Westinghouse, Universal Cyclops, and others are working on experimental new alloys on which no data are available.

FIGURE 5: Fabricating temperatures for refractory metals. Columbium and tantalum are usually formed at room temperature; only heavy sections are slightly heated for spinning. For both molybdenum and its 0.5Ti alloy, the relationship between metal thickness and fabricating temperature is nearly linear. For tungsten, too, fabricating temperatures increase with thickness; furthermore, much higher temperatures are needed for sheet bending than for shearing and stamping.



New resins lead

structural plastics development

- Several approaches used to get higher temperatures
- Filament winding is favored

by E. J. Zeilberger and J. H. Lieb,
Supervisor and Senior Research Engineer,
Materials Engineering, Rocketdyne Div.,
North American Aviation, Inc *

FIGURE 1: Small propellant tank combines circumferential and helical filament winding. The hemispherical metal end fittings support the break-away mandrel during winding. The wound-in mounting brackets are held in place by the circumferential wrap.

IN HIGH TEMPERATURE resins, steady, if unspectacular, progress has been made in the past few years. Improvements now are the results of modification and copolymerization of well-known resin types rather than of the discovery of radically new polymers. This situation probably will remain unchanged until research in inorganic polymers produces marketable materials.

Examples of recent progress are the phenyl-silane copolymers, epoxy-novolacs, and peracetic-acid-type diepoxides. These resins all were developed to meet increasing temperature requirements. The phenyl-silanes were designed to add to the high strength of phenolics the thermal stability of the silicones. They have added about 200 deg F to the upper temperature limit of the standard phenolics (*Fig. 2*).

The strengths reached by phenyl-silane are not so

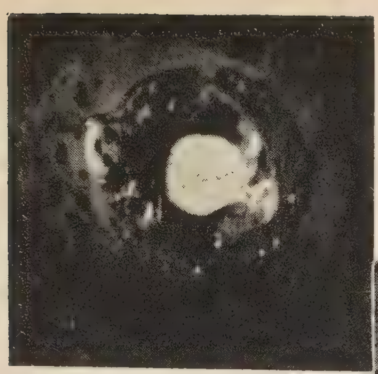
* Rocketdyne Div., North American Aviation, Inc., Canoga Park, Calif.

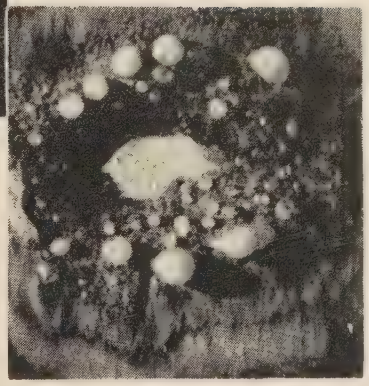
Table I: Properties of Phenolics

	Ultimate Flexural Strength (psi)		Flexural Modulus (psi)		Thermal Conductivity from 100 to 500 Deg F (Btu-in./hr-sq-ft-deg F)
	At Room Temperature	At 500 Deg F	At Room Temperature	At 500 Deg F	
Refrasil	25,000	3.1×10^6	19,000		1.2-2
Glass phenolic	50,000	3×10^6	40,000	3×10^6	approx. 1.8
Asbestos phenolic	50,000	5×10^6	45,000	4.5×10^6	0.87-1.49

Table II: Specific Design Strengths

17-7PH Cres steel	520,000
410 Cres steel	490,000
4130 Cres steel	480,000
6061-T6 Al	350,000
7075 T6 Al	650,000
8Mn Ti	700.000
Fiberglass epoxy (non-directional)	740,000





EFFECTS of exposure to a 5000-deg F oxy-hydrogen torch on steel, glass-reinforced, and quartz-fiber-reinforced panels. (l. to r.) The exposure time for quartz was more than three times longer than for the other samples.

high as those of straight phenolic. However, the temperature curve of this copolymer is quite flat, so you can depend on reasonably uniform properties over a wide temperature range. Since the phenyl-silanes are quite new, we can assume that resin improvements will push its room-temperature flexural strength beyond 80,000 psi in the near future.

The epoxy-novolac resins achieve heat stability through high "functionality", which is the term for the reactive sites in a resin molecule. The more of these sites there are, the greater will be the degree of cross-linking when the final space lattice is formed and the more stable the resin. The high softening points and resistance to degradation of resins largely depend on the functionality of the starting material. Standard epoxy resins—even in a purified state—cannot have a functionality greater than 2. The epoxy-novolacs have a functionality of 3-4 and so offer almost twice as good an opportunity for reaction.

The more highly cross-linked structure of the epoxy-novolacs and the rigid, short methyl linkage between their phenyl groups appreciably improve physical properties. After anhydride cures, heat distortion temperatures of 568 deg F have been reported for resins of this type.

This is about 135 deg F higher than the values reported for conventional epoxies cured in the same way. *Figure 2* also shows the effect of temperature on the flexural strength of epoxy-novolacs.

Distortion points as high as 572°

Recently several diepoxides based on derivatives of cyclohexene oxide have been introduced. In this peracetic-acid type resin, at least one epoxy group is attached directly to a phenolic ring with a closely packed molecular structure. Resins of this type cure quickly with various anhydrides in the presence of basic catalysts and have heat distortion points as high as 572 deg F.

The flexural-strength curve for this resin type is quite flat to 400 deg F. Room-temperature strengths, however, are not so high as those for bisphenol A or the novolac resins.

The study of cure systems for this resin type is just starting. It is expected that resin systems with improved handling characteristics and properties will result. *Figure 2* shows that, while bisphenol-type resins fall below 40,000 psi at about 300 deg F, the novolac types keep this strength beyond 400 and the peracetic-acid types beyond 500 deg F.

Among high temperature reinforcing materials, the first material to be explored was Thompson Fiber Glass' Refrasil, made by acid-leaching glass fibers until all their materials except silica are extracted. The remaining porous structure then is sintered at high temperature. It shrinks and pulls the almost pure silica fibers together. Refrasil has only about 25 per cent of the strength of glass fibers, but the useful-strength temper-

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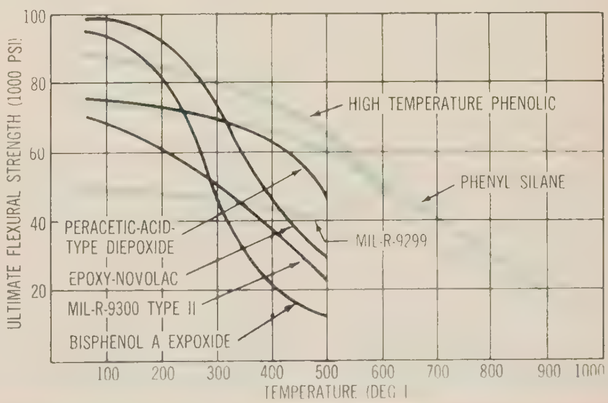
FIGURE 2: Flexural strengths of laminates of typical phenolic resins and 181 glass fabric in tests at temperature after half an hour at temperature.



ature limit is increased by almost 300 per cent.

Refrasil laminates have their greatest potential between 1500 and 2500 deg F. Some typical applications of Refrasil are in rocket engine parts, nose cones, and heat insulation shields.

An even higher temperature reinforcing material is quartz. The advantages of quartz fiber over materials like Refrasil are that its original strength is somewhat greater, its modulus of elasticity is very close to that of E-glass, and its usable-temperature range extends to slightly higher values. Continuous length quartz filaments are commercially available.

The big drawback of this material is price—quartz fibers still are about $60 a pound.

Cooling through good dehydration

Asbestos is becoming a leader among heat protection laminates. Asbestos felts combined with phenolic resins have about twice the room-temperature strength of Refrasil laminates and comparable strength retention at 500 deg F (*Table I*).

Another advantage of asbestos-based laminates is that asbestos starts to dehydrate at 600 deg F, with dehydration continuing to 2000 deg F. Dehydration has a cooling effect, since it uses up heat for the vaporization of moisture.

Programs sponsored by BuAer and WADC's Materials Lab have led to a unique reinforcing material—high modulus glass. This new glass has a modulus of better than $1.8x10^7$, as against about 10^7 for E-glass. This development will enable the designer to use the ultimate in strength in his laminates, yet have a thin structure that won't deform too much. The new glass also will result in a better match of moduli for composite structures of metal and fiberglass-reinforced plastic. This match is important in designing metal liners and fittings for tanks, solid propellant rocket casings, etc.

The main problem with the new glass is that the increase in modulus is achieved by the addition of beryllium oxide, and beryllium and its salts and oxides are considered extremely toxic. Researchers therefore are trying to find out whether beryllium in high modulus glass may not exist only as a complex silicate and therefore be relatively harmless.

In the production of the new resins and reinforcements, filament winding has been attracting the greatest attention. With this versatile process, shapes are produced by winding and curing a continuous, resin-impregnated roving of yarn strand on a mandrel. Its applications range from the nose spike of the Lockheed X-7 to the combustion chamber of the Thor IRBM.

Hoop strengths of 180,-200,000 psi

Wound parts are being made with hoop strengths of 180,-200,000 psi. At 200,000 psi, fiber-glass-reinforced epoxies with a specific gravity of 2.1 have a specific design strength (strength divided by density) of 2,640,-000 in. (*Table II*).

Although few current designs achieve 200,000 psi, 150,-160,000 psi is fairly common, and higher values are not far off. Special test parts made at Rocketdyne have achieved room-temperature tensile strengths of 225-250,000 psi and room-temperature flexural strengths of 275,-300,000 psi.

When a metal layer takes some of the stresses in a composite design, filament winding is used as an external reinforcement over a metal structure, so that no further mandrel or winding form is needed. Large liquid-propellant thrust chambers with a circumferentially wound glass fiber epoxy resin reinforcement over a basic metal structure have been fired for many hundreds of seconds at rated thrust without failure of the reinforcement.

In other cases, a very thin, impermeable liner of metal or rubber is needed. For designs in which the fiber-glass-reinforced plastic is the sole load-carrying member, mandrels made of low-melting alloy, breakaway plaster, or wax therefore are used.

The problems of casting a mandrel that may weigh many tons and of handling it must be carefully thought out. In selecting mandrel materials, you have to consider the effects of heated resins, hot-air blowers, or heat lamps as used during winding.

Figure 1 shows a small propellant tank that uses both circumferential and helical winding. This construction gives a better distribution of hoop and longitudinal properties.

Successful filament winding of radomes largely depends on maintaining a uniform resin content and very close mechanical tolerance. To insure the necessary accuracy, sometimes the same machine is used for grinding the mandrel, winding the structure, and machining the final contours.

Most filament winding applications so far use epoxy and polyester resins. These are handled readily in a 100 per cent solids, wet winding operation. The application of phenolics to filament winding has been delayed by two problems:

- The phenolics are not available as 100 per cent reactive systems, but only as "varnishes" or solvent solutions.
- They cure by condensation reactions that form gaseous byproducts, which in turn reduce the cure pressure and lead to porous structures.

Reactivity problem may be solved

Pre-impregnated, B-staged roving appears to offer a workable solution to the first problem and is being studied closely by several firms. Such a material, however, will require new winding methods.

Research on glass-reinforced materials for ablative nose cones and heat shields several years ago led to discoveries about fiber orientation that are applied widely today. Researchers found that, if the fabric orientation presents the ends of the reinforcing filaments to the high speed gas stream, high temperature performance is far better than if the gas flow is parallel to the fabric layers and so to the filament axis.

The so-called end-grain configuration makes reinforced plastics even more suitable for extreme temperature designs than they have always been. With each filament axis normal to the surface exposed to the gas flow, the exposed tip may melt, but the buried end is securely held in the cool inner part of the laminate. The latter therefore erodes uniformly, and there can be no sloughing off of complete layers.

End-grain tapes are available in glass, Refrasil, and asbestos. They are used in nozzle designs, with the tape wound on a mandrel so that the filaments are all normal to the nozzle axis. Such a construction is highly erosion-resistant, buts its physical strength is low. External reinforcement, either filament- or fabric-tape-wound, is generally used.—End

Bonding and welding:

ideal for new aerospace materials

Basic studies of bonding and welding pave the way for wider use of these processes on new materials

Bonding

by George D. Cremer, Senior Staff Engineer, Solar Aircraft Co.*

STRUCTURAL SANDWICH assemblies offer the best way of combining aerospace materials in configurations with maximum strength-weight ratios. They may be bonded with adhesives or ceramics or by brazing, welding, or solid-phase diffusion. In addition, attempts are being made to develop "unbonded" integral core-to-facing structures by inflating a specially prepared metal sheet (e.g., "tube-in-strip") or by laying up an integral fabric sandwich that is then resin-impregnated and cured.

Adhesive bonding is widely applied. It uses fairly low temperatures (room temperatures to 450 deg F) and provides low cost production of complex, large assemblies. The wide variety of lay-up and curing methods includes hand-wrap, vacuum-bag, steam- or hot-air-autoclave, hot-platen-press, oil-bag-platen, electric-blanket, and dielectric-heating techniques.

Military specs adhesives limit current service tem-

* Solar Aircraft Co., San Diego 12, Calif.

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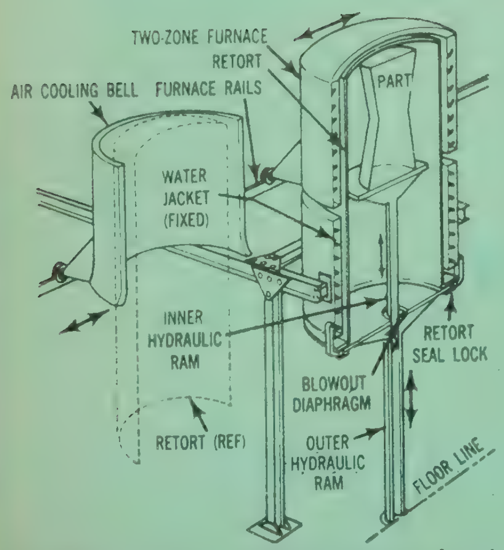
COPPER-BRAZED hydrogen-oxygen rocket engine following the first-stage assembly of a stainless steel channel core with a ribbon-wrap outer facing. Fuel manifolds and external support rings are still to be secured by a second brazing operation.



ADVANCED RETORT combines furnace and cooling system into a single facility. The furnace moves horizontally and the retort vertically. Parts within the retort may be independently raised or lowered.

Silver Brazing Alloys

Up to 600 deg F	Easy-Flo No. 3
Up to 800 deg F	silver manganese 85/15, silver-copper-lithium 92.8/7/.2

High-Temperature Corrosion-Resistant Brazing Alloys

Up to 1100 deg F	Solabraze H
Up to 1500 deg F	Solabraze I, IXI, MNX
Up to 1500 deg F	Coast 50
Up to 1800 deg F	Coast 53
1500-1800 deg F	Solabraze NXI
Up to 1900 deg F	Nicrobraz
Up to 2000 deg F	GE 81, GE 81 Modified, Solabraze NX77

peratures from —67 to 500 deg F. But researchers hope to develop adhesives for very low as well as very high temperatures. New inorganic polymers and ceramic adhesives are among the possibilities under study.

Braze bonding complements adhesive bonding by extending the useful temperatures at both high and low extremes. For instance, brazed-steel sandwiches can operate from absolute zero to at least 2100 deg F. Specially brazed molybdenum sandwiches look promising for 3000 deg F, and brazed tungsten structures could undoubtedly push the ceiling to over 4000 deg F.

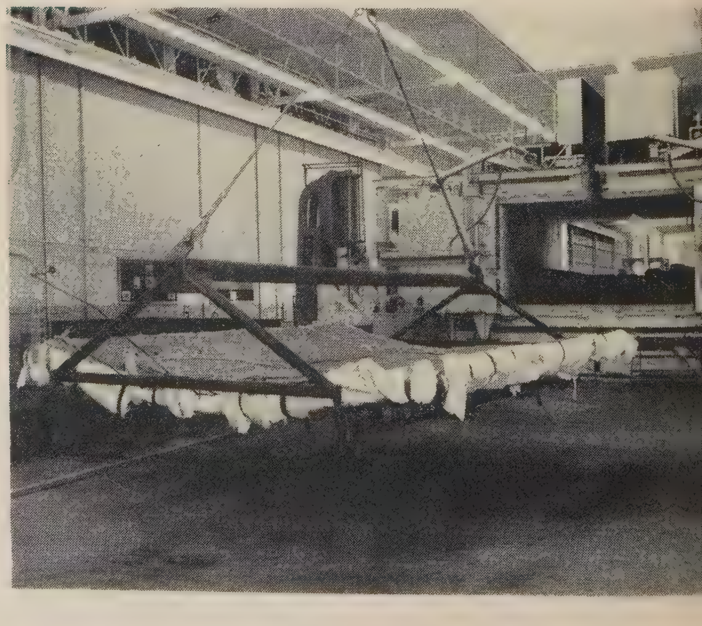
Braze bonding is a high temperature metallurgical process that calls for highly specialized heating equipment. The protective bonding atmosphere, heat distribution and rate, brazing alloy flow, confining pressure, cooling cycle, and heat treatment all must be precisely controlled.

Silver-base alloys are used for bonding heat-treatable stainless steels of the 17-7PH and PH15-7Mo type for sustained service temperatures of 800 deg F maximum. (The B-58 and B-70 airframes use sterling silver plus lithium.) A low-conductivity modification of this silver bonding technique has been developed recently by throwing in a little palladium and indium. This addition substantially improves the heat insulation value.

Corrosion-resistant nickel-base brazing alloys are used to join high temperature structural base metals like T-321, 19-9D1, A-286, Inconel and Inconel X, Hastelloy B and , R-235, René 41, and Haynes Alloy 25. For special applications, structural sandwiches may also be bonded with gold and palladium alloys.

Several furnace designs are available for precision brazing. The important thing is that the furnace be able to heat and cool the sandwich rapidly and uniformly while maintaining an accurate support. Individually controlled heat zones are a must. Auxiliary means must also be provided for fast, programed cooling that will not distort the precision reference tool fixtures or die blocks.

Other brazing heat sources are under development. They include designs that use electric blankets, quartz lamps, salt baths, direct resistance, moving heat zones,



"LUMINOUS-WALL" Holden furnace at NAA being loaded with a 10x14-ft curved honeycomb panel assembly. The encapsulated part will be evenly supported on insulated piers while it is heated from all sides to about 1625 deg F for braze bonding. Fuel gas-air mixture combusts on porous furnace walls, floors, and doors. The gas is turned off but the air is left flowing for rapid, controlled cooling.

induction furnaces, or exothermic chemical reactions. Other major R&D efforts of bonding researchers are aimed at:

- a better understanding of bonding chemistry and metallurgy and of bonding parameters in general;
- the development of controllable heat sources with uniform outputs for low cost curing or maturing of the adhesive and flowing of the braze metal;
- techniques for joining sandwich subassemblies into larger assemblies by means of mechanical fasteners or by welding;
- the development of low cost, non-destructive testing and inspection techniques.

The ultimate in materials of construction for sandwich structures may well be at hand once we can use beryllium-base alloys. Combined with adhesive bonding, these may provide the optimum sandwich structure. End

Welding

by G. W. Oyler, Head, Electric Welding, Development Laboratory, Linde Co.*

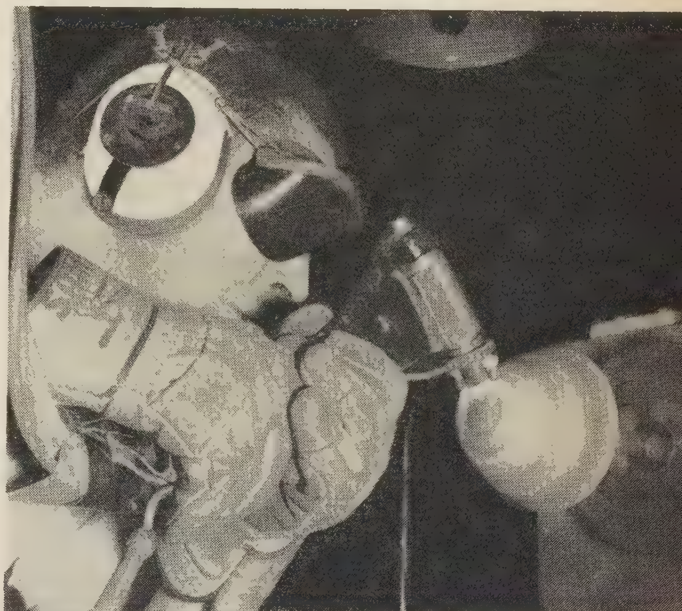
THE MAJOR welding processes fall into three categories: arc welding, gas welding, and resistance welding. Arc welding processes most likely will be used on space vehicles, because of weld soundness and durability. Gas, or oxy-acetylene, welding has disadvantages—excessive base metal heating and oxidation—that make it unsuitable for modern metals. Resistance welding involves pressure, which often leads to distortion, and is unsuitable for joining in all cases in which the strength-weight ratio is of prime importance.

The arc-welding methods themselves fall into three groups: inert-gas shielded-arc welding, submerged-arc welding, and covered-electrode arc welding. The last two are limited chiefly to ferous alloys. It is the inert-gas shielded-arc welding processes—which may use a consumable or a non-consumable electrode—that have revolutionized metal fabrication in the aerospace industry. In a controlled atmosphere, you can use them to weld all metals—even such exotic ones as zirconium alloys and hafnium.

These welding processes use either a tungsten electrode arc (with the electrode virtually unconsumable) or a consumable arc. The tungsten-arc process is suited primarily to thin sheet under ⅛ in. In critical applications, it has also been used on thick plate. This type of welding can be done manually in all positions, it is also easily mechanized.

Consumable-arc welding is suitable for all types of metals over a wide range of thicknesses of more than 0.05 in. Filler metal, which can be precisely matched to the base metal, may be deposited at rates 2-4 times higher than those of other applicable welding methods. Manual welds can be made in any position. For automatic production welding, which calls for the deposition of 20-30 lb of weld metal per hour, the process is limited essentially to the flat position.

Tungsten-arc spot-welding is accepted as ideal for quality spot welds when only one side of a joint is accessible or two or more metal pieces of varying thickness are to be joined. The welding action is controlled by the current input to the arc and the time during which the arc dwells on the work. Inert gas (usually argon) protects the weld puddle and the unconsumable tungsten electrode from contamination.



HEAT-RESISTANT tungsten coating of a missile nose structure. The operator wears ear muffs as protection against the high-pitched noise of the plasma arc torch.

Consumable-electrode spot-welding is used mainly for heavy-duty work on metals like stainless steel and aluminum. The rapid-feed electrode easily joins overlapping sheets of metal with thicknesses from 0.04 to 0.125 in. Full-penetration plugs can be made in 0.125-0.25-in.-thick metal with no sink after welding. Metal sheets may also be spaced, since the welds will penetrate the first sheet.

To extend the use of inert-gas shielded-arc welding to new metals, researchers have gone back to the fundamentals—to detailed studies of the welding process

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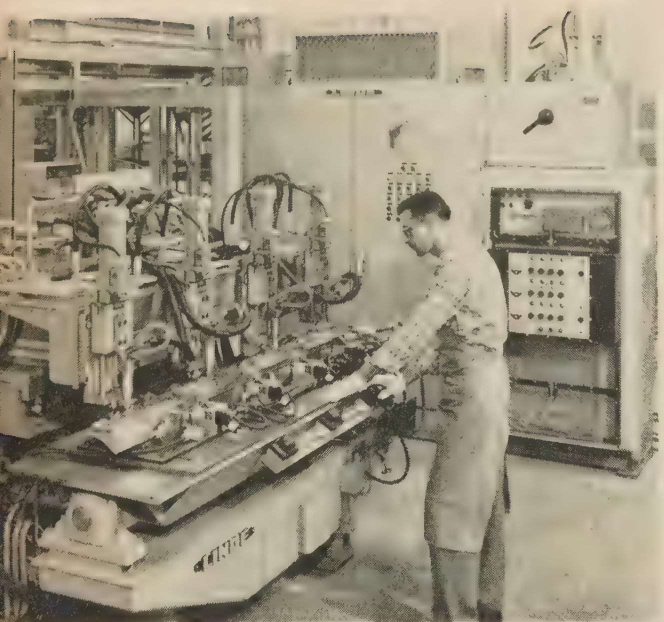


PUNCHED-TAPE spot-welding machine set up to make some 2520 spot welds an hour on a missile fin production run. The machine uses an inert-gas tungsten-arc process with a pilot arc.

and its physical application, its electronic controls and circuits, and the metallurgy of the new materials. New application techniques are constantly being devised. In power supplies, for instance, important recent developments include:

- the three-phase rectified power source, which rectifies the output of three separate-phase transformers and combines them into a single power output;
- the constant-potential power source, with which the arc current can be varied while the voltage across the arc is held constant;
- the slope-controlled constant-potential power source, which produces a closely regulated arc for precise welding heat control.

One of the most important recent breakthroughs in circuitry was the development of the pilot arc for automated tungsten-arc spot-welding. A continuous arc between electrode and torch nozzle keeps a small ball of incandescent and ionized gas in the cup of the torch. As the torch approaches the workpiece, the pilot arc provides an ionized gas path for instant, reliable starting.

With the introduction of the short-arc process for consumable-electrode welding, it's been possible to weld extremely thin sheets of metal at high speed. The process was made possible by the development of the slope-controlled power source, a small-diameter wire feeding device, and the availability of efficient shielding gas.

Conventional, and even constant-potential, power sources give too much arc heat for thin-gage welding. The result is uncontrolled melting and an excess of filler metal. The slope-controlled constant-potential power source produces a "cool" arc that is short-circuited 100-200 times per second. In this way, the arc heat is pinpointed, a small cold puddle is produced, and consumable-electrode can be applied to materials only 0.02-0.1 in. thick.

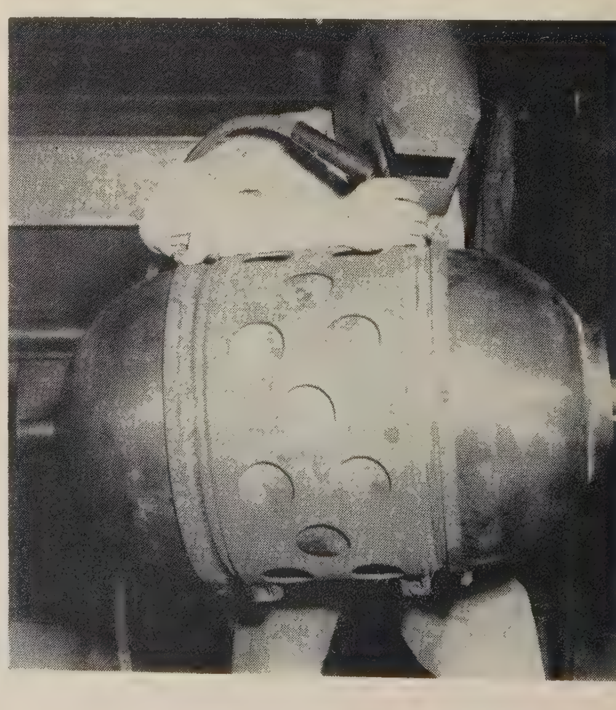
The operator can weld in all positions—downhand, vertical, or overhead—and needs only a minimum of skill. The arc normally operates at 30-125 amp and 14-19 V on virtually all metals. Argon or an argon-carbon dioxide mixture is the usual shielding gas. The wire feed uses 0.02- and 0.03-in.-diameter stock.

Tungsten-arc cutting and plasma-arc coating are other important welding advances. Both processes use a "constricted arc" that is extremely hot and has a high velocity.

Tungsten-arc cutting uses an arc transferred from the electrode to the workpiece and severely constricted by a small opening at the torch nozzle. The arc is backed up by a large flow of argon-hydrogen gas that sharply increases the arc's velocity. The result is an intense ionized jet that will produce a high quality cut in all modern metals—from thin stainless to three-inch magnesium and aluminum—at speeds up to 1000 ipm.

Plasma-arc coating uses an untransferred arc (i.e., an arc between electrode and nozzle). A large flow of argon or hydrogen gas forces the arc out through a constricted opening in the nozzle. The result is a plasma jet of ionized gasses and free electrons at temperatures of up to 30,000 deg K.

The welding material—which may be tungsten or a high-melting carbide—can be fed into the torch in either powder or wire form. It is melted and carried from the nozzle at near sonic speed. The ultra-hard material is then blasted onto a spinning carbon or metal part to form a hard, dense coating. The material strikes the workpiece in a molten or plastic state and is immediately cooled by sprays of carbon dioxide gas.—End



INERT-GAS tungsten arc welding of rocket casing girth seams of Vanguard's third stage.

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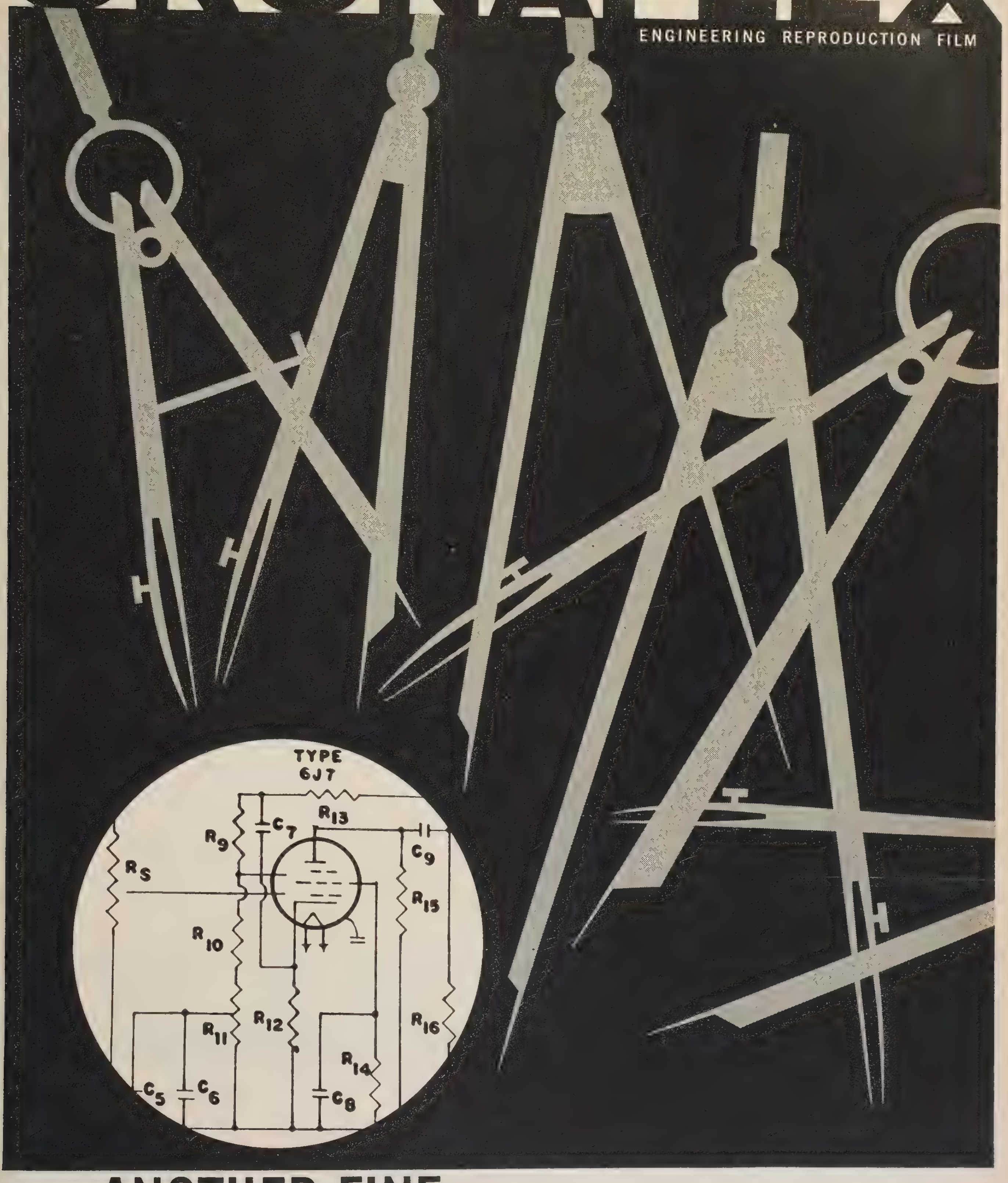

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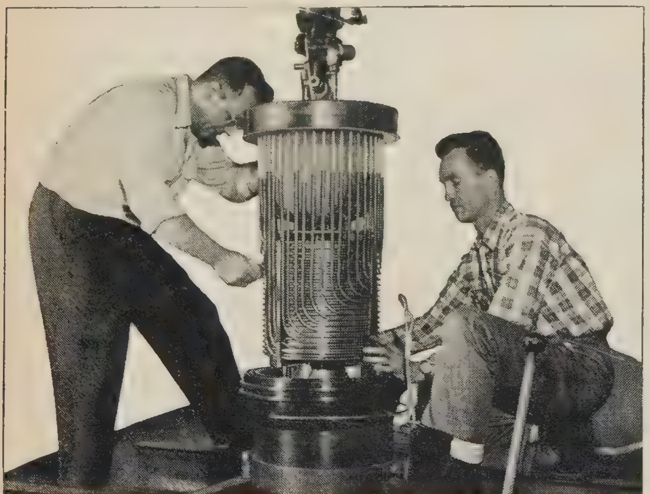
BISHOP Tubular Products NEWS

"METALS FOR PRECISION AND PERFORMANCE"

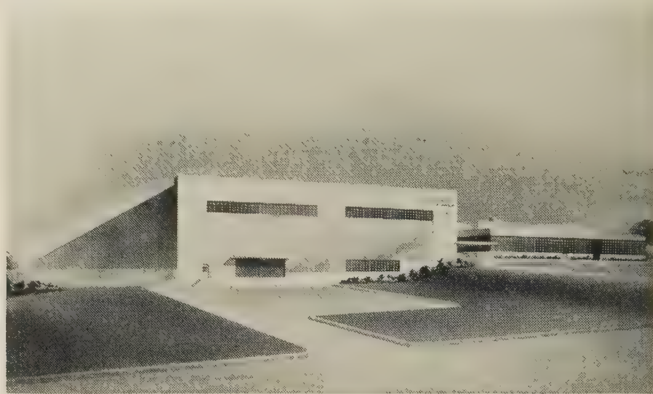
GOLD-CLAD STAINLESS TUBING CURBS CORROSION IN REACTOR

Photo pictures insertion of gold-clad stainless steel heat exchanger into gold-clad power reactor at AEC's Los Alamos Scientific Laboratory. Completely successful in recent operational tests, the unique reactor is designed to produce superheated steam in a single pass. This is the second experimental reactor using uranyl phosphate fuel—the first unit failed because of excessive corrosion in the heat exchanger. Gold-cladding now protects all structural parts in contact with the extremely corrosive solution.

Will clad metals solve *your* corrosion problems? Investigate the BISHOP line of clad metals. BISHOP was the first company to successfully produce gold-clad stainless tubing . . . coupon brings data. Use it.



NEW BISHOP TUBE MILL OPENS



Sketch shows new BISHOP facilities adjacent to the present tube mill in East Whiteland Township, west of Paoli, Penna.—completing the first stage in BISHOP's long range expansion program. This two-story structure will contain over 165,000 square feet of floor space. BISHOP platinum mechanical manufacturing operations also move to the East Whiteland plant.

BISHOP NOW DRAWING .002″ WALL TANTALUM TUBING

Tantalum tubing with paper-thin wall thicknesses is now being supplied by BISHOP on special order. Sizes range from .062 in. OD x .002 in. wall to 1.5 in. OD x .125 in. wall. Columbium (niobium) tubing down to .002 in. wall has been produced and is also available. Can tubing of these "exotic" metals be the answer to any of your design problems? Check with BISHOP . . . use the coupon.

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DETECTION, TRACKING, ACQUISITION AND FIRE CONTROL

The General Precision companies are applying a broad knowledge of radar, including airborne Doppler techniques, to development of new systems for target detection and acquisition, missile velocity measurement and fire control.

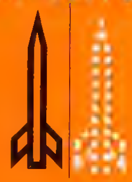
Servo components, microwave components and stable platforms for these systems are designed and manufactured within the group.

This work has led to research in related areas such as high resolution radar and advanced infrared techniques.

An optical tracking device developed and manufactured within the group is being used in a series of space explorations to photograph planets for the first time from outside the earth's atmosphere. This balloon-borne Star Tracker device locks a larger telescope onto its target and enables it to hold the planet's image within one second of arc. A study program on a stellar comparator is also underway.

A large part of the fire control equipment for advanced U.S. Navy surface and subsurface antisubmarine warfare programs is being developed and produced within the group.

SIMULATION, TEST AND GROUND SUPPORT



Training equipment for virtually every type of fighter and bomber in the armed forces is produced in the group.

Progress in human engineering techniques is resulting also in development of simulators designed around sophisticated man-machine concepts—simulators for missile training and for duplication of space flight conditions and submarine operations.

In the field of go-no-go missile test equipment, systems-oriented equipment has been developed which has built-in "reasoning" processes and is capable of reacting to given stimuli.

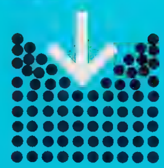
For example, these systems automatically and continuously test products, systems and components, retaining each test result and rejecting or approving according to pre-programmed standards. Research is being done on "intelligent" machines which one day could devise and build other machines and perform other complex functions, using learning and adaptive processes similar to those of man.

Group technologies have been combined to produce complete ground support checkout equipment including analog, analog-digital hybrid systems, fully digital checkout and programming techniques and automatic electronic components inspection. Another capability is an electronic system called TRACER* for accurate control and unique identification of mobile units and personnel.

General Precision television equipment is in use for remote observation of jet and rocket engines, missile and weapon firings and nuclear reactor operations, for underwater surveillance and visual systems in jet aircraft simulators.

*TRADEMARK

MANUFACTURING SKILLS IN DYNAMICS



Manufacturing military products today depends not only on precision mechanics but also upon scientific application of skills in dynamics—the use of dynamic forces to measure the extreme tolerances required for component and system work.

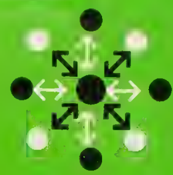
Specially designed equipment is used for this purpose in the General Precision companies. One example: a FRINGE-COUNT* Micrometer, which provides measurements to a millionth of an inch using the wavelength of light as its standard.

Manufacturing with electrons and protons as basic cutting tools, or in controlled quantities as building blocks, is already well advanced in the group. Thin film technology—the deposition of thin films of various materials measured in angstroms—is being developed for unique new components.

Modern facilities for manufacturing and testing within the group include complete environmental laboratories for simulation of all conditions a system or component is likely to encounter, ultra-clean assembly facilities for guidance components, and an unsurpassed temperature-controlled metrology laboratory.

*TRADEMARK

MANAGEMENT AND CORPORATE STRENGTH



The ability of the General Precision group to manage programs on the technical, production and financial levels is demonstrated by a number of important assignments.

One is the prime contract for the key portion of the FAA airways modernization program—the Data Processing Central. This is the most comprehensive systems engineering job ever undertaken for air traffic control, and involves several associate contractor companies outside the group.

Considerable experience has been acquired also through the systems management of a number of ASW warfare and other military programs.

The managements of the four companies and of General Precision determine which company or team is best qualified to carry out specific programs. Financing for all programs also is provided through the parent corporation.

In addition, the group can call on the resources of other General Precision companies—including capabilities in electrical and electronic, photographic and process control fields.

Although these affiliated companies serve mostly non-military markets, their skills are contributing to the solution of defense problems. Recent examples: development of a heat exchanger for a nuclear aircraft engine, and production of the first U. S. military searchlight incorporating a 2,000 candles/mm² light source.

The General Precision companies operate nationwide facilities occupying over 2,500,000 square feet of floor space and employ over 16,000 people—4,500 of whom are scientists, engineers and technicians.

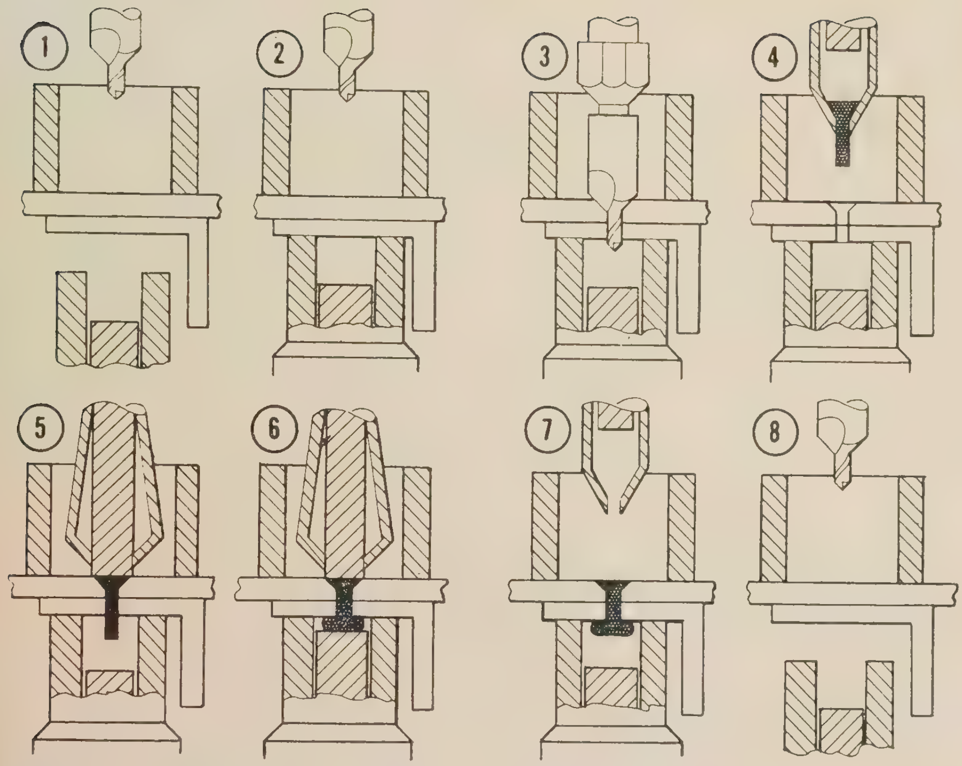


FIGURE 1: In automatic riveting, the work piece starts from the "at rest" position (1). The lower anvil then rises (2) to clamp the piece against the upper anvil pressure foot. At a predetermined damping pressure, the drill or the drill countersink comes down (3) at predetermined feed rate and speed. At the same time, the fastener is inserted in the holding fingers of the rivet anvil (4). The drill spindle is then moved away, and the rivet positioned above the hole (5). The lower anvil upsets the rivet (6) and is retracted (7). The clamping pressure is released and the drill spindle returned (8).

New materials pose problems for

mechanical joining

- Radically new fastener techniques coming up
- Induction-heating dimpling holds promise
- Extensive use of automation is forecast

by Irwin Stambler, Associate Editor

THE continuing trend in aerospace structures is to use fewer and fewer mechanical fasteners. However, it's obvious that some fasteners will have to be used in many areas of even the most advanced vehicles—on access doors, on panels that must be removed for repairs, on leading-edge surfaces, on heavy fittings, etc. Rivets and bolts will also continue to find wide use in areas in which high temperatures aren't a problem.

The rapidly increasing performance needs of new designs demand fasteners with ever higher strength, closer tolerance, and greater temperature resistance. In addition, the trend toward superalloys, "exotic" materials, honeycomb structure, etc., calls for radically new methods.

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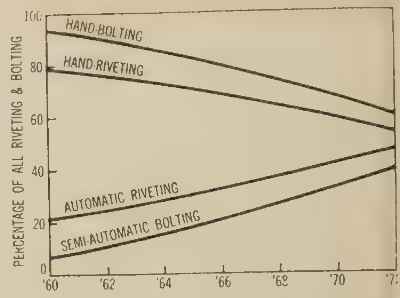

FIGURE 2: Though automatic riveting has been around for some years, AIA survey shows hand-riveting still accounts for the lion's share of fastening. AIA panel expects automatic and semi-automatic mechanical joining methods to increase rapidly in the next decade.

of hole preparation and fastener installation.

Even today's new transport designs are making vastly greater demands on fasteners. E. A. Green, manager of the Production Engineering Dept. at Lockheed-Burbank, points as a case in point that advanced aircraft studies showed that, in some environments (such as intense vibration), fasteners tend to loosen that never gave any trouble in past designs. As a result, there's great interest in methods for getting much higher torques on current fasteners.

Stronger fasteners also save weight

Weight reduction, of course, is another reason for going to higher strength fasteners. In the Electra, high strength fasteners have already been upped in heat-treat from 120,000 to 160,000 psi. Lockheed is now looking at such items as 220,000-psi Vascojet 1000 fasteners. Because of their high strength properties, such fasteners might be used even where temperature isn't a problem, Lockheed engineers note.

Green also points out that methods of cadmium plating have been developed to keep 260,000-psi 4340 steel from embrittling. It's also felt that the thread rolling problem for 260,000-psi materials has been solved. Pins of this strength are being used in the Electra landing gear.

Fastener geometry is being carefully studied to find ways of

more on page 7[illegible]

Table I: Dimpling Characteristics of B-120VCA 13V-11Cr-3AC Titanium Sheet[1]

Gage (in.)	Temperature (deg F)	Results	Appearance
0.026	RT	satisfactory	slight orange peel
	200	satisfactory	slight orange peel
	400	satisfactory	orange peel
	600	satisfactory	orange peel
	800	satisfactory	orange peel
0.029	RT	satisfactory	slight orange peel
	200	satisfactory	orange peel
	400	satisfactory	orange peel
	600	satisfactory	slight orange peel
	800	failure[2]	slight orange peel
0.032	RT	satisfactory	orange peel
	200	satisfactory	orange peel
	400	slight failure[2]	orange peel
	600	failure[2]	orange peel
	800	failure[2]	orange peel
0.033	RT	failure[2]	slight orange peel
	200	satisfactory	slight orange peel
	400	satisfactory	slight orange peel
	600	satisfactory	slight orange peel
	800	slight failure[2]	orange peel

(1) Dimple size—No 10-32 flat-head machine screw, 100-deg included angle (2) By cracking

cutting weight. One approach is to hollow out the upper head surface of bolts. More compact nuts make it possible to reduce the bolt length. A recent modified lightweight hex nut, Green points out, promises to save up to 50 lb on each Electra.

One of the difficulties with the high strength fasteners, W. A. Dickie, chief engineer at Hi-Shear Rivet Tool, states, is that they require harder materials with less elongation. This means they're limited when it comes to redistributing loads. Hole preparation—alignment, countersink, dimpling, etc.—therefore becomes critical. On the fastener itself, Dickie notes, more attention must be given to such points as surface finish, rolling fillets, recess configurations, etc.

A great deal of study is going into close-tolerance hole preparation in high strength materials. Battelle Memorial studies stress the fact that drill life decreases rapidly in high strength steels as hardness increases in the 45- 55-R_C range.* Even variations of one number in workpiece hardness affect drill life, it's reported. Very rigid, high-powered equipment is needed, and the work must be properly backed up and supported to eliminate deflection under load.

Careful handling and meticulous inspection of high hardness steel parts are required throughout processing. Nicks, scratches, scribed lines, etc., must be eliminated from the finish-machined part, Battelle states, because of their adverse effect on fatigue life.

Table II gives some of the data obtained by Battelle. However, since very small details of drill geometry, drill heat treat, and setup rigidity can have major effects these data should only be used as guides. For newer materials, such as beryllium, new drilling methods must be devised (*Fig. 2*).

New dimpling methods are needed

Work is also continuing on new ways to dimple high strength materials in the hardened condition (*Table I*). The consensus of opinion, J. R. Hendel, of Northrop, recently told an SAE meeting, is that conventional conduction-heat dimpling (by either flow-forming or ramcoining) can only be used up to the dimpling range of 800-900 deg. F.

* Gerds, Olofson & Boulger, "Drilling High Strength Steels Heat-Treated to 330-560 Brinell Hardness," DMIC Memo 31, Aug. '59.

more on page 78

TODAY'S modern aircraft and weapons systems demand reliable ground support that can only be developed through experience. The thousands of AEI elements of support equipment now in service have demonstrated their rugged dependability and have gained for American Electronics a position of leadership in the industry. As a result, American Electronics is producing ground support equipment for most of the nation's newest space programs.

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**Table II: Drilling High
High Speed**

Hardness		Speed
BHN	Rc	(sfm)
327-371	35-40	30-40
371-421	40-45	25-35
421-481	45-50	15-25
481-560	50-55	7-15

Steel	Hardness		Drill
	BHN	Rc	Steel (AISI)
4130	341	36	M-2
Halcomb 218	341	36	M-2
UHS 260	341	36	M-2
Unimach 2	352	38	M-2
4340	340	36	M-2
	482	50	T-15
	514	52	T-15
	514	52	T-15
	514	52	T-15
Vascojet 1000	375	40	M-2
17-22AS	352	38	M-2

*General data are for speeds and feeds at which the included drill angle usually is 130-150 deg. Sometimes the corners are chamfered to reduce wear. Lip relief angles are kept small for maximum cutting lip support. The drill chisel edge must be as short as possible—thinning of the drill web may be necessary. Split points are commonly used up to 49 Rc. Above this hardness, various kinds of notch thinning or modified split points that leave

Most of the upcoming materials unfortunately require at least 1300 deg F, and some call for 1800-2000 deg F. At these temperatures, conventional dimpling dies quickly break down.

Resistance heating, a new approach to hot dimpling, he stated, has shown some promise but is difficult to control, Hendel stated. Its problems include arcing, spot heating, die heating, etc.

One of the most promising new dimpling techniques is induction heating. Good results have been achieved, Hendel reported, with heat-treated 17-7Ph, AM 350, 15-7Mo, and 4-3-1-titanium at 1300-1400 deg F and with A110-AT at 1600-1700 deg F. With the PH steels, though, permanent partial annealing occurred at the dimple.

Cold rotary impact-dimpling, another new method, has worked well with softer materials, and some titaniums. However, it hasn't worked too well so far with harder materials, Hendel said, except that it produced very good results when

rength Steels with
eel Drills*

Feed (ipr)		
<1/8	1/8-1/4	1/4-1/2
0.001-0.003	0.002-0.005	0.004-0.009
0.001-0.002	0.002-0.004	0.003-0.007
0.0005-0.0015	0.001-0.003	0.002-0.005
0.0005-0.0010	0.001-0.002	0.002-0.004

peed (fpm)	Feed (ipr)	No. of Holes Drilled before 0.015-in. Wearland
110	0.002	100
100	0.002	100
95	0.002	100
80	0.002	100
68	0.002	100
50	0.005	100
30	0.0005	100
30	0.001	103
20	0.0005	20
20	0.001	34
30	0.0005	23
40	0.001	22
40	0.005	17
	0.001	
67	0.002	100
60	0.002	100

a small chisel edge can be used.
The data for specific steels are for 2¾-in. long ¼-in. drills. Helix angles of 29 deg, clearance angles of seven degrees, and point angles of 118 and 90 deg—for steels around 340 B and above 480 B, respectively—are used. Up to 100 per cent longer drill life can be expected if crankshaft (split) point grind is used instead of the standard point grind.

used to punch holes to very close tolerances in harder materials of up to 280,000 psi.

As *Figure 1* shows, over the next decade the trend in production joining methods points to the extensive use of automation. Lockheed now is using automatic Drivmatic riveting machines on the Electra line for both aluminum and steel fasteners (*Fig. 3*). The same machine is used in both cases; special drills and hoppers are installed for steel.

Wing lap joints for bolts in steel

In the steel operation, Huckbolts and Hi-Loks are being installed in wing lap joints. Enough foot pressure is obtained, engineers state, so that the joints (which are presealed) can be drilled without getting chips into them. For aluminum, the Drivmatics are run with a clamping pressure of about 600 lb; for steel, 1000 lb is used.

Most of the Drivmatics are run

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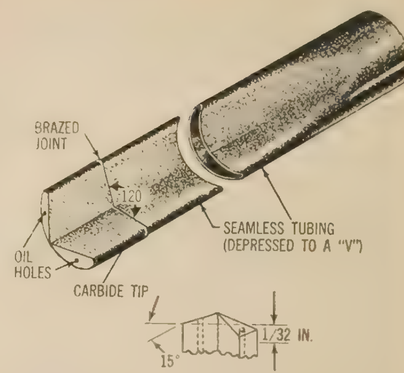
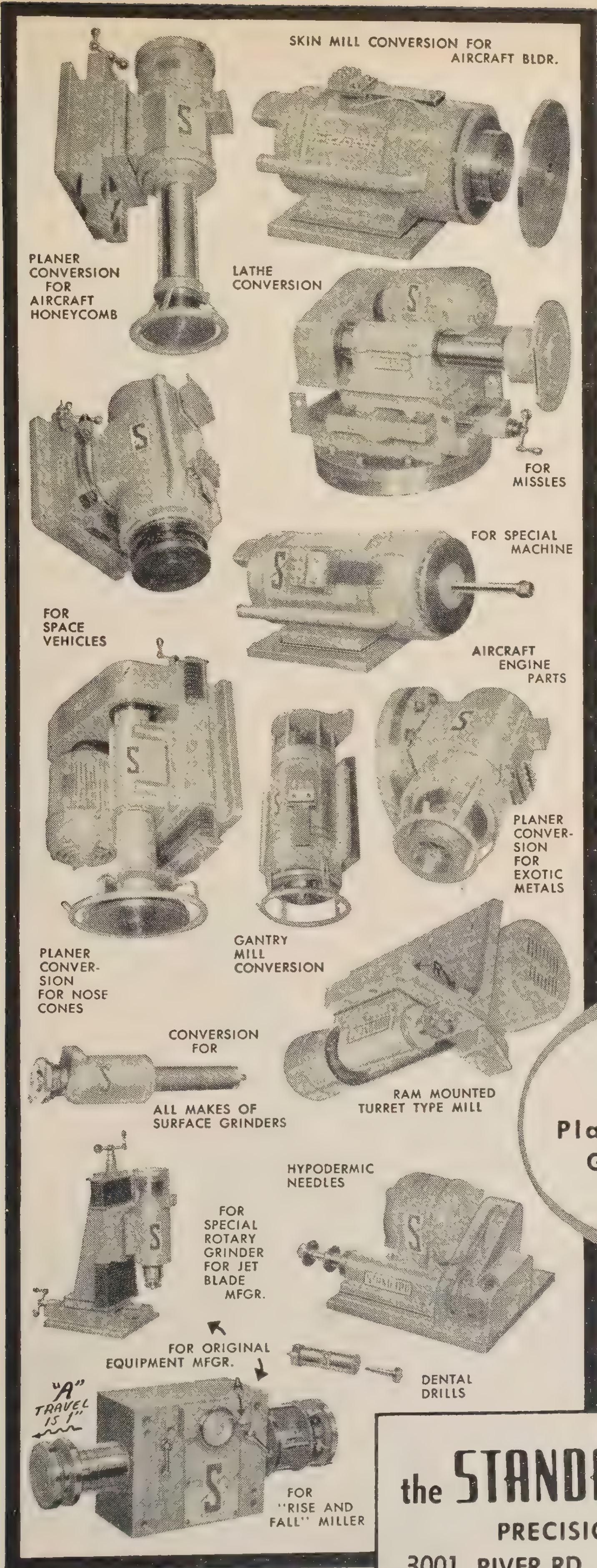


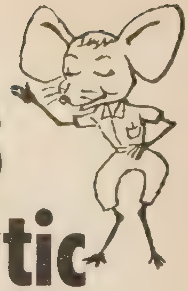
FIGURE 3: "Exotic" structural materials like beryllium, tantalum, molybdenum, etc., call for new mechanical joining approaches. This carbide-tipped rifle drill is used in deep hole drilling of beryllium at Battelle.

by tape control. However, one was just converted to a Lockheed numerical-control system using IBM cards. The tape setup has one drawback: The units must be indexed from time to time to compensate for different coefficients of expansion between tape and aluminum.

Lockheed's Georgia Div. is working with a new Erco slug rivet machine that installs the rivet, upsets both sides at once, and then mills one side flush. This unit is still in R&D, but reportedly it looks promising. Eventually, Lockheed intends to use it in fuel tank assembly.—End

TIME-HONORED hand riveting process, used here in assembly of Convair 880 wing spar, is expected to give way to more and more automatic techniques.





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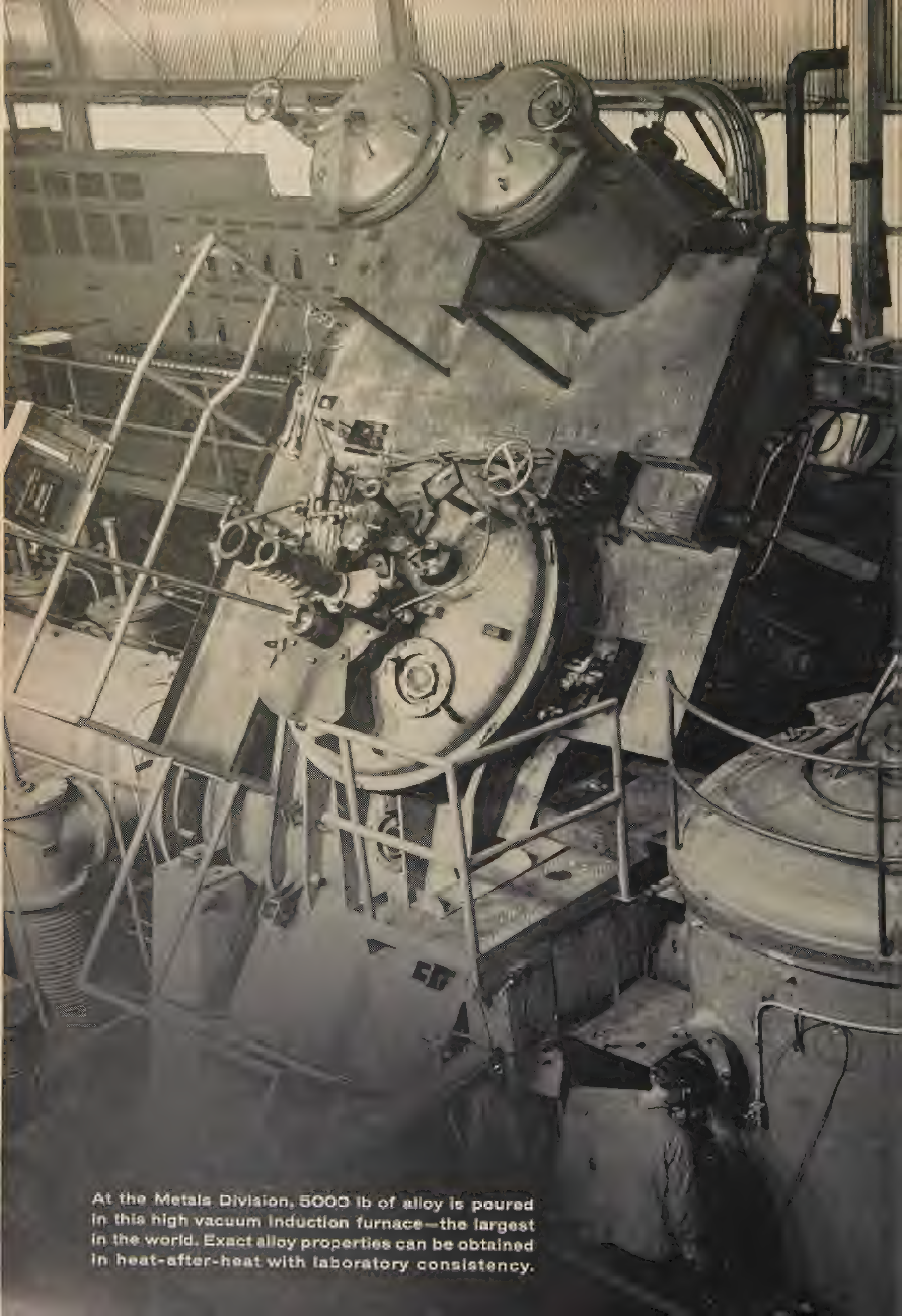
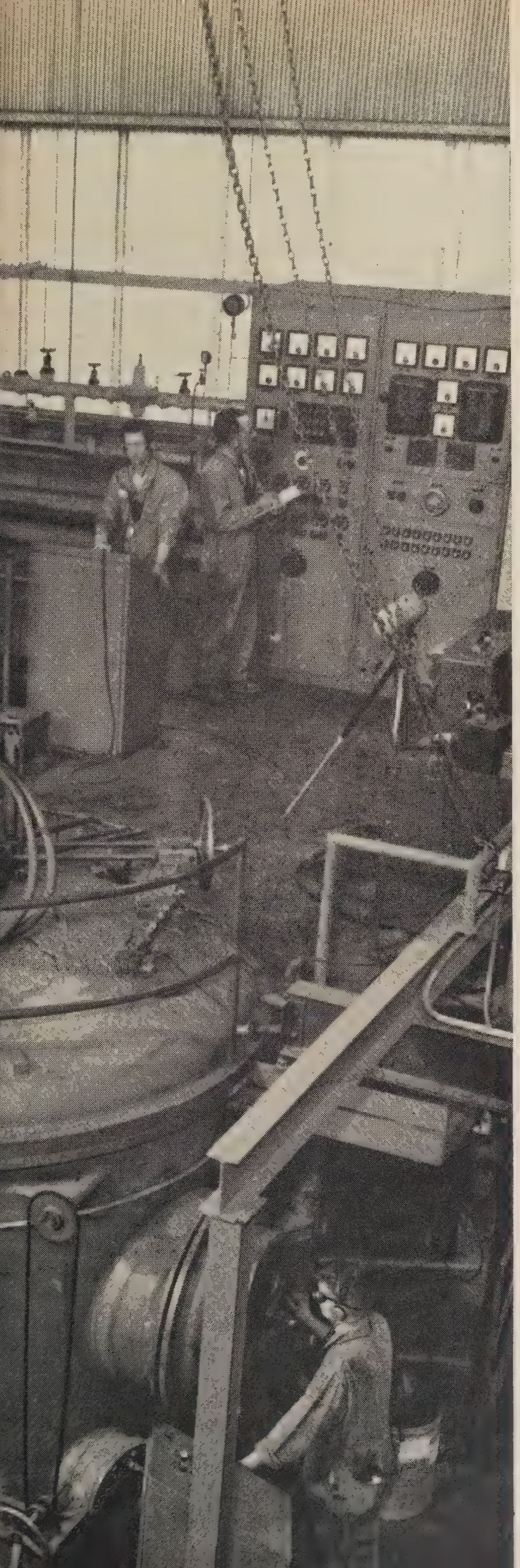
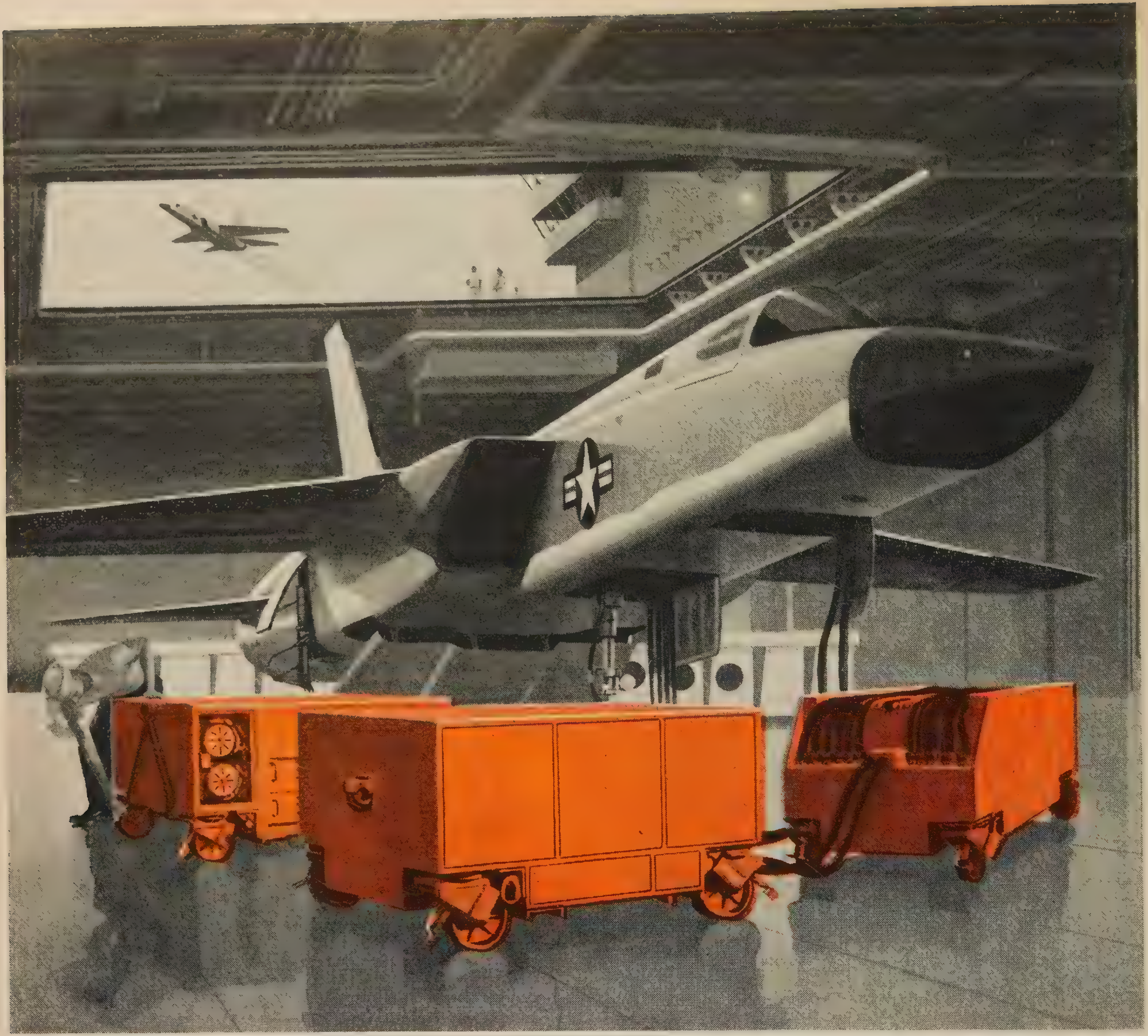


At the Metals Division, 5000 lb of alloy is poured in this high vacuum induction furnace—the largest in the world. Exact alloy properties can be obtained in heat-after-heat with laboratory consistency.





Who put the cart before the horsepower?

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Result: carts that contain today's most versatile automatic checkout systems. These systems match the needs of the majority of manned and unmanned weapon systems. Adaptive equipment for testing special electronic systems can be packaged in similar carts and plugged into the basic cart. The system is thus complete and readily mobile.

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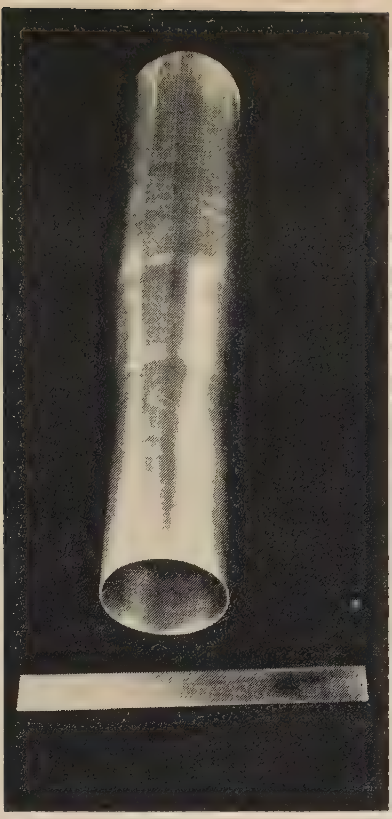


FIGURE 1: Transition duct, formerly made of two transition-section-welded tubes, is now Dynaformed in one shot as a single piece. The Convair technique causes little thinning, since the material is shot from the top and the smaller section literally is driven into the larger.

production
& materials
engineering

9

New techniques, greater precision for forming processes

- Larger, more rigid power spinning machines
- Precision forgings of advanced materials
- High-energy-rate forming looks promising

PART I

IN AEROSPACE structural design we are apparently due to complete a full circle. Until recently, the trend has been away from built-up structures to the wide use of integral structure. But now we seem to be moving back once more to built-up methods (*Fig. 2*). The reason, an Aircraft Industries Association study reports, is mainly that "the high mechanical properties of the future sheet materials can be most efficiently utilized by built-up structure design. To achieve equivalent efficiency in an integral structure, complete machining would be required."

While this development points to wider use of advanced sheet working methods—such as high energy rate forming and/or power spinning—conventional forging and extrusion processes will still be important. Perhaps the current intensive work on improved precision forging, casting, and extruding will result in even wider use of these methods than seems conceivable right now.

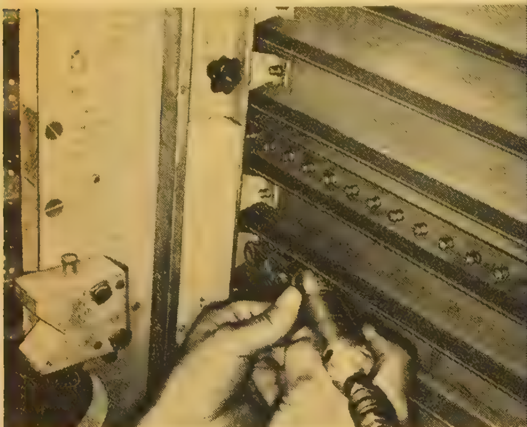
In power spinning, or roll forming, a great deal of effort is being put into the development of larger more rigid machines as well as of machines that will be precise enough to spin hemispheres with a wider range of wall thicknesses.

As J. W. Heater, of Harron, Rickard & McCone, told a recent ASTE meeting, "experience shows that rather small, thin-walled hemispheres can be produced from flat disks in a single pass where reduction of wall is 50 per cent. Some success has been had with bowl-shaped preforms on larger hemispheres. [However] as the metal thickness . . . reaches ¼ in. and more, the volume of metal radially displaced begins to defy control, resulting in failure." Heater noted that we need processing methods for hemispheres that will give us the desired wall thickness control without extensive machining. Better ways of spinning nozzle-shaped parts and elliptical, semi-elliptical, and hemispherical pressure vessel shapes are also being sought.

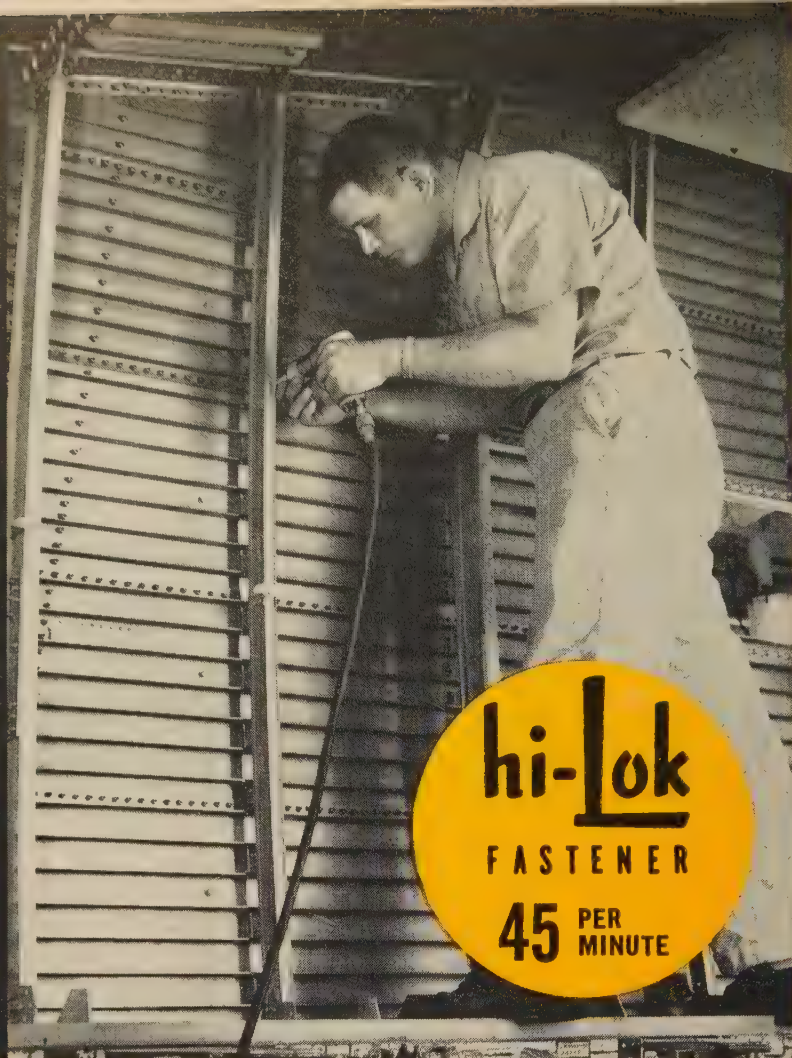
Until recently, most power spinning machines were vertical units, but the new large capacity devices will be horizontal types. One of the newest to go into operation is the Hufford "spin forge," which can apply a total work force of over a million pounds in forming parts 10 ft high and up to 60 in. in diameter. The spin forge recently delivered to Marquardt Aircraft is 25 ft wide, 24 ft high (including base) and weighs over 450,000 lb. It met specs calling for a 50 per cent

more on page 87

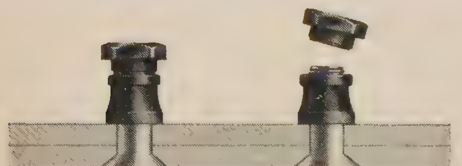
THE HI-LOK AUTOMATIC FEED DRIVER, FITTED TO AN INGERSOLL-RAND AIR MOTOR, ASSEMBLES UP TO 200 COLLARS ONTO HI-LOK PINS WITHOUT RELOADING. ASSEMBLY RATE: UP TO 45 PER MINUTE.



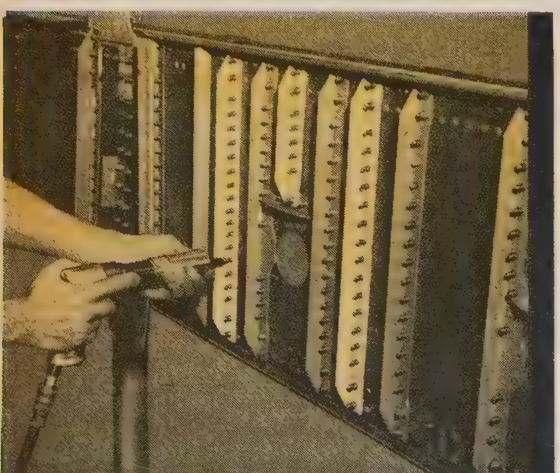
HI-LOK IS BEING ASSEMBLED UNDER WING RIB IN EXTREMELY TIGHT QUARTERS USING A HI-LOK 20° RATCHET WRENCH ATTACHMENT AND KELLER AIR MOTOR.



HI-LOK IS BEING INSTALLED WITH LIGHTWEIGHT TOOLING IN PLANK SPLICE OF ELECTRA "WET" WING.



WRENCHING END OF HI-LOK COLLAR AUTOMATICALLY TORQUES-OFF WHEN DESIGN PRELOAD CONDITION IS ATTAINED DURING ASSEMBLY.



MINIMUM TOOL CLEARANCE CONDITIONS ON STIFFENERS IN WING FRONT SPAR ARE EASILY MET WITH HI-LOK ADAPTOR TOOLING COMBINED WITH INGERSOLL-RAND AIR MOTOR.

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Table I: Usual Forging Temperatures for Titanium Alloys (deg F)

	Blocking[1]	Finishing
Unalloyed Ti	1425-1600[2]	1425-1500
8Mn Ti (alpha-beta)	1550-1700	1300-1400
6Al-4V Ti (alpha-beta)	1625-1725[3]	1550-1600
4Al-4Mn Ti (alpha-beta)	1600-1700	1500-1550[4]
3Al-5Cr Ti (alpha-beta)	1650-1750	1500-1550
5Al-1.5Fe-1.4Cr-1.2Mo Ti (alpha-beta)	1750-1800	1650-1750
7Al-3Mo Ti (alpha-beta)	1700-1950	1800-1850
5Al-2.5Sn Ti (alpha)	1750-1800	1650-1850

(1) Heavy drafts or reductions are taken in blocking.
(2) One fabricator reports going to 1700 deg F furnace temperature.
(3) One fabricator reports going to 1900 deg F furnace temperature.
(4) One fabricator reports going to 1600 deg F furnace temperature.

reduction of one-inch 321 stainless in a single pass at ±0.002 in. tolerance and using a force of 225,000 lb up, down, and in and out on the cross slide, and 100,000 lb up and 200,000 lb down on the tailstock. (See *S/A, "Faster Forming of Complex Parts with Spin Forging," May '59, p. 69.*)

Larger types are already in development. For instance, Loewy Hydropress is working on a new series of machines ranging up to 100 in. in diameter.

In forging, it seems unlikely that any presses larger than the new 35,- and 50,000-ton closed-die hydraulic types should be in the offing. Most of the effort in this area is aimed at the more efficient use of these new presses—through reduced die costs or better lubricating methods. On one new lubricating technique, the surface of the billet is pre-treated with lubricant before forging. Battelle Memorial Institute reports that a large improvement in die filling results. Close control of die temperature has also been shown to provide better forgings.

In the production of smaller forgings, Battelle reports, cored forging looks promising. This technique uses presses with a top punch in the ram and two side punches actuated by a pitman from the main crank beneath the press bed. It has been successfully applied to titanium parts, and its use with other metals is being studied.

A great deal of work is going into the development of forging methods for high strength materials like titanium, beryllium and the refractory metals. One breakthrough, of course, was the recent successful closed-die forging of beryllium by Wyman-Gordon.

Many research groups are studying forging techniques for advanced materials. Among the materials Battelle's working on are molybdenum, titanium, and zirconium.

Battelle consultant H. B. Goodwin reports that molybdenum must be extruded before it can be forged: "Arc-cast molybdenum ingots are extruded at 2300-2400 deg F . . . forging or rolling of either extrusions or . . . powder metallurgy products is usually begun at about the same temperatures. The temperature is sometimes pushed to 2600 deg F for easier workability, but [then] the mechanical properties suffer." Battelle states that for unalloyed molybdenum the practical lower forging temperature is about 1700 deg F; for the 0.5Ti alloy, it is 1900 deg F.

Zirconium, molybdenum, and titanium, it's reported, are usually worked on equipment designed for working steel. Zirconium, says

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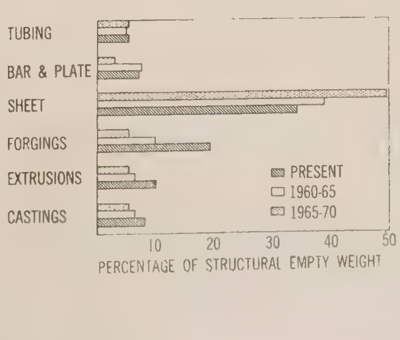
FIGURE 2: AIA study of production trends forecasts vastly increased use of sheet forms in next decade's vehicles.



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LGP-30

Engineers in the aircraft and missile field get answers *fast* when they have direct access to the powerful LGP-30 electronic computer marketed by Royal McBee. Many are now solving such problems as wind tunnel and flight test data reduction, guidance system design, transducer calibrations, flutter and vibration studies, component reliability evaluations, specific impulse calculations and thermal stress distribution—*at desk-side!* Reason: this computer is programmed and operated by the engineer himself to cut through the maze of mathematical calculations demanded by today's complex aircraft design requirements.

The LGP-30 is low in cost – about the price of a good engineer – and is simple to program and operate. Its 4096-word memory is comparable to computers many times its size and cost. User-engineers develop a man-machine relationship to the point where it becomes an extension of their own thinking capacity. Bolder, more creative engineering almost always results.

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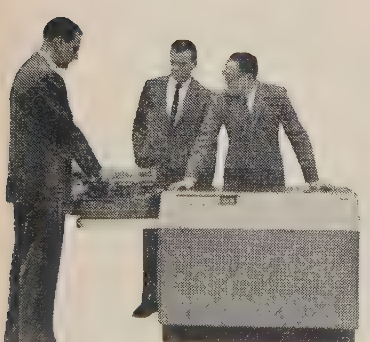

Royal Precision Corporation

Royal Precision is jointly owned by the Royal McBee and General Precision Equipment Corporations. LGP-30 sales and service are available coast-to-coast, in Canada and abroad through Royal McBee Data Processing offices. For information on the LGP-30 write **ROYAL McBEE CORPORATION**, data processing division, Port Chester, New York

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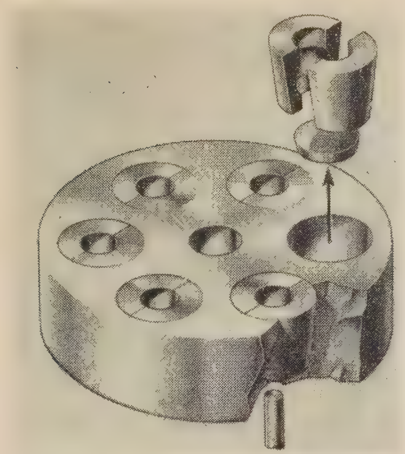

FIGURE 3: Typical production die holder for explosive forming of several parts in one shot. With the turntable arrangement, dies and parts can be released successively from the die holder.

Table II: Forging Pressure for Titanium and Steel (tons/sq in.)*

Unalloyed Ti	40-50
4Al-4Mn Ti	75
2Fe-2Cr-2Mo Ti	75
1.5Fe-2.75Cr Ti	75
5Al-1.5Fe-1.4Cr-1.2Mo Ti	85
5Al-2.75Cr-1.25Fe Ti	100
6Al-4V Ti	100
7Al-3Mo Ti	100
5Al-2.5Sn Ti	120
SAE 4340 steel	20

*At normal forging temperatures and under comparable conditions.

Goodwin, has a wide how-workability temperature range, since it becomes very malleable. The range of temperatures to which the metal is heated before forging is 1550-1700 deg F. *Tables I & II* show some of the titanium forging data obtained by Battelle.

The key question for the future of forgings in the aerospace industry is whether it will be possible to make precision forgings in the high strength materials. A. G. Jones, of North American Aviation, recently told ASTE that R&D stainless steel and titanium forgings have been produced that needed a machine clean-up only on contact or working surfaces. The more impressive features of such parts, he stated, include web thicknesses down to 0.094 in., cavity or pocket depth to 1¼ in. with no-draft walls, and curves and contours forged to finish dimensions and surface roughness requirements.

However, rejection rates and costs have been very high, said Jones, and difficulties have cropped up. It's still too early to tell whether it would ever be economical to produce such parts, he concluded.

Precision castings and extrusions are becoming more important (*Table III*). One of the newer processes used for the latter is called "precision cold-extruding." The word "cold" here refers to the fact that the extrusion temperature is below the recrystallization temperature. R. A. Quadt, of Bridgeport Brass, recently told ASTE, that parts produced by [precision cold-extruding] will be work-hardened and [show] increasing strengths and hardnesses, depending on the severity of the cross-sectional reduction."

The advantages of precision cold-extruding, Quadt stated, include:

- There is no hydrogen, nitrogen, or carbon pickup.
- No volatile or surface oxides are formed.
- Reactive metals need not be clad.
- Inherently higher recoveries are available.
- Precise shapes can be produced with little or no secondary machining needed.
- Higher strengths are obtained, thanks to the work-hardened structure.

Bridgeport Brass' Hunter Douglas Div., in Riverside, Calif., has developed a series of special hydraulic presses precision cold-extruding, ranging from 200 to 3500 tons. The largest, said Quadt, has a maximum ram deflection of 0.002 in. over a 108-in. power stroke. Parts up to 20 in. in diameters and 40 ft long have been formed.

On precision castings, American Brake Shoe recently announced that it is developing a new method to make high integrity steel castings. The company's process is claimed to eliminate flaws and to provide uniform tensiles as high as 300,000 psi. Parts can be made in almost any size from a few pounds to thousands of pounds, it's re-

more on page 91

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Table III: Typical Manufacturing Limits on the Size of Extrusions[1]

Press Capacity (tons)	Container ID (in.)	Max. Circle (in.)[2]	Approx. Pressure on (psi)
1600	6		100,000
2400	6	4⅞	
	7	5¾	
2500	6	4⅞	157,000
	8	6½	93,000
	9	7¼	74,000
2750	7	5¾	
	8	6½	
3850	8	6½	
	9	7¼	
	11[3]	9¼[3]	
4250	9	7¼	126,000
	11	9¼	86,000
	14	12	52,000
	16	14	41,000
5500	11	9¼	
	14	12	
	16	14	
		17	

(1) From "ARDC Production Design Handbook and excluding the newest extrusion presses, such as those of 8000 tons capacity. These have maximum circles of up to 27 in. (2) The maximum (circumscribing) circle is defined as the diameter of the minimum circle completely enveloping the desired shape. (3) at weghts of 190-325 lb and lengths of 22-36 in.

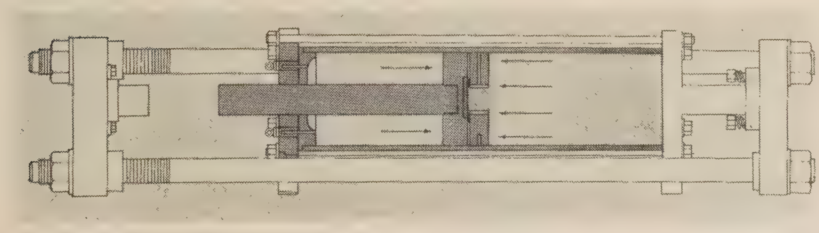

FIGURE 4: Cross-section of Dynapak metal-working machine. High pressure gas is stored in the chamber at left. Relatively low pressure gas in the right-hand chamber forces the piston against the orifice plate, while the seal in the piston face isolates the entire piston surface from the high pressure gas, except for a small area surrounded by the seal. Slight added pressure at the left starts the piston moving, disengaging the seal and letting the high pressure gas push against the entire face of the piston, which moves at speeds as high as 2500 fps.

ported. The process requires close control of all steps and careful selection of raw materials and alloying elements. Molds are made of a special ceramic to produce controlled shrinkage rates as the casting cools.

In sheet forming, U.S. Steel has a USAF contract to refine the recent breakthrough in rolling light gage steel sheets in widths previously considered impractical. Work will be done on materials like 4340 and hot-work die steels. It's hoped that sheets 120 in. wide, up to 360 in. long, and 0.01 in. thick or heavier will be produced to tolerances only 25 per cent as large as those for commercial sheet in a flat condition.

Larger stretch-wrap-form machines are also becoming available. An example is a 50-ton radial draw former from Cyril Bath, recently installed at Convair-Astro-

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Check Employment Inquiry Form on Page 217

Solid Fuels are simple—

nautics. It is 92 ft long and weighs over 100 tons, with a stretching maximum of 50 tons and a minimum of two tons. It will radial-form a 48-in. stainless steel sheet.

PART II

by E. W. Feddersen and J. A. Elder, Chief, Manufacturing Research & Development, & Engineering Publications Editor, resp., Convair-Ft. Worth*

ONE OF the most promising new forming methods is the high-energy-rate process. A "high energy rate" in this connection implies a very great power that's efficiently and forcibly exerted at speeds of over 100 fps. A special case of this new process is explosive forming, which the energy of the shock wave and the expanding gas bubble from a chemical explosion in a fluid (usually water) is used to change the shape of a material. Convair's explosive-forming method, known as "Dynaforming," has already been programed for production parts fabrication (*Figs. 1 & 3*).

We have classified present production part shapes into four categories:

- preformed hollow bodies that are expanded,
- cup shapes drawn from flat planes,
- flat and contoured panels,
- straight and curved channels.

The first two categories offer the greatest potential for explosive forming. The other two don't lend themselves well to the new process; they are produced much more cheaply by conventional drop-hammer or hydropress methods.

The natural shape of a plate exposed to explosive forming and allowed to deform freely is approximately parabolic. It follows that shapes based on or developed from a parabolic curve are ideally suited to the new method. So are cylindrical, spherical, and conical shapes, in whose case explosive forming is easily combined with bending and deep-drawing.

The equipment required for explosive forming is simple, consisting essentially of a water tank and die handling and storage facilities. The Convair installation, which cost an estimated $30,000, will handle the same maximum-size parts as would normally require a hydraulic press costing about $1,600,000. Also, explosive forming requires only one die, while most other forming methods require two.

The process itself imposes no limitations. Parts of any size can be formed, so long as you have enough space in which to set off the desired explosion.

Dies don't have to be submerged in a water tank. Instead, a water container can be designed as an integral part of the die so that the work piece serves as a part of the tank bottom. The most serious practical limitation is imposed by the handling equipment for the large, heavy dies.

From a production standpoint, Dynaforming has two drawbacks: It lacks controls and there is no repeatability. To overcome these problems, Convair has developed three new high-energy-rate metal-working machines, the first of which is the Dynapak (*Fig. 4*). This machine is used to forge, extrude, compact, shear, and blank metals and other materials. It's only 25 per cent as large and heavy as conventional tools. Reliable, simple to operate, and inexpensive, it produces precision parts that can't be shaped by conventional machine tools.

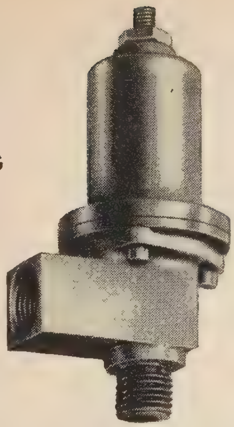
The model 1200 Dynapak, a 12-in. bore machine can develop energies of 160,000 ft-lb but is only three feet wide, three feet high, and 12 ft long. It's fastened to the floor by only six bolts. The floor loading is almost zero.

Though not all the phenomena they involve are fully understood yet, the high-energy-rate processes nevertheless represent a metal-working breakthrough. It appears that many metals, including high strength, high temperature steel, have hydrodynamic behavior—they flow as if they were plastic. High-energy-rate forming therefore may open up an entirely new metal-working approach, in which high pressures are rapidly applied to more material as a fluid.

Because of the extremely high pressures it generates, Dynapak produces parts that can't be made in any other way. For instance, it extrudes parts with web thicknesses of 0.01 in. and forges to zero draft angle. Eventually, such performance could lead to parts that are "born to shape" in an optimum design and require very little or no machine finishing.—End

* Convair Div., General Dynamics Corp., Grant's Lane, Ft. Worth 1, Texas

PROPELLANT FLOW MODULATING AND PRESSURE REGULATING VALVE



The problem of operating hot gas generators at a specified constant pressure level led to the design, test and development of the liquid fuel regulating valve pictured here.

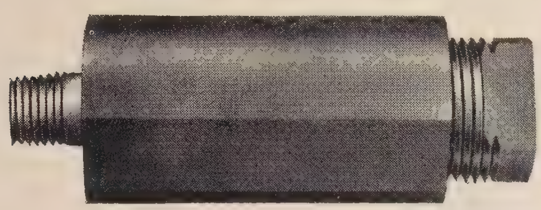
This valve may be described as a spring-loaded, spool-type throttling valve. Full open when the pressure at its outlet port (gas generator pressure) is low, it progressively closes off as the outlet pressure increases.

With minimum leakage an important objective, the valve shown meets the following specification:

Flow (hydrazine)	.002 to .02 lb./sec.
Upstream pressure	500 to 3000 psi
Regulated pressure	500 to 2000 psi
Temperature	0° to 200°F.
Weight	.38 lb.
Size	1.75″ O.D. x 3.00″

Limited changes in regulated pressure can readily be accomplished by means of a simple adjustment screw. Broader changes in regulated pressure or in flow capacity can be accomplished through slight re-design of the spool or spring elements.

SOLID PROPELLANT HOT GAS FILTER

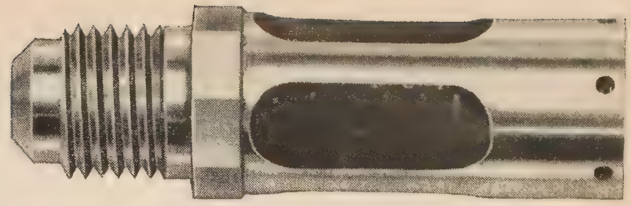


Since small-orifice areas of servo valves cannot tolerate contaminants produced by combustion of solid propellants, CECO found it necessary to develop the special hot gas filter shown here. Unlike those heretofore available, this filter can easily be cleaned for re-use and has amply demonstrated its ability to withstand the temperatures and pressures encountered in hot gas systems.

It operates as follows: hot gas flows into an annulus between the filter element and housing, then diffuses through to the outer surface of the element, depositing solid particles as it goes. With gas flow at .015 lb./sec., this filter operates for several minutes, with average contamination, filtering out particles as fine as 10 microns.

Representative specification:

Operating temperature	to 1800°F.
Operating pressure	to 2000 psi
Initial pressure drop at .015 lb./sec.	2 psi @ 1000 psi
Filter housing size	1.38 O.D.″ x 5.00″
Weight	.88 lb.

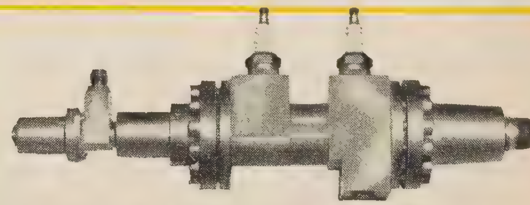


HOT GAS PRESSURE RELIEF VALVE

Typical of component hardware developed by CECO in its work with hot gas servo actuation and reaction systems is the valve pictured here. While it can easily be modified to satisfy other requirements, specification for the valve shown is as follows:

Relief pressure	1000 psi*
Reseat pressure	950 psi
Flow	.02 lb./sec. @ 1000 psi
Temperature	1800°F.
Weight	.032 lb.

* *Adjustable from 800 to 1200 psi.*



HOT GAS REACTION CHAMBER FOR LABORATORY USE

This unit is used as a "workhorse" hydrazine reaction chamber to provide clean, hot, high-pressure gas for test purposes.

Ideal for laboratory use, its flow rates range between .001 and .1 lb. sec., and may be extended in either direction by changing nozzle and load orifice sizes. Operating temperatures are between 1200°F. and 1800°F. with pressures to 2000 psi.

The chamber is preheated by an electrical coil, a feature which facilitates repetitive starting without need for disassembly between test runs to renew the catalyst.

The above picture shows CECO's generator with the pressure regulating and flow modulating valve in position. For those who require a complete, "packaged" system for providing a continuous supply of hot gas, Chandler Evans can supply a complete laboratory model hot gas generator system including the fuel storage, pressurizing, purging and pressure regulating elements in addition to the gas generator reaction chamber described above.

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Literature, including a reprint of this ad, available by request to Department 69.

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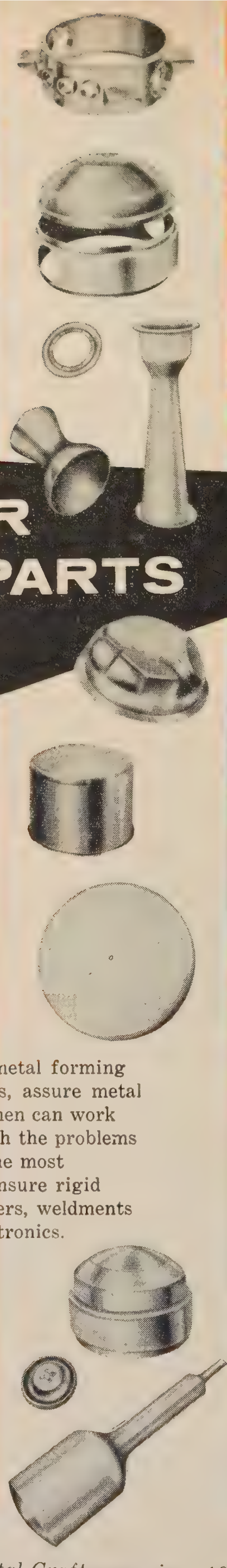

Numerical control
comes into its own

- Even small computers suitable for numerical lofting
- Further expansion foreseen through APT projects

by Arthur F. Eskelin, Manufacturing R&D Engineer, Norair Div., Northrop Corp.*

THE "blue sky" theory of putting an equation into a high speed electronic computer and coming out with a punched or magnetic tape that can machine an airplane wing is not far from reality. Equations for a complete wing of a wind tunnel model have been processed through a small electronic computer. The result was an output tape controlling all motions needed to machine the entire airfoil surface of the wind.

An even better example is the fuselage of the Northrop N-156F fighter. All of it is defined in equation form and stored on punched tape. In minutes, data

* Norair Div., Northrop Corp., 1001 Broadway, Hawthorne, Calif.

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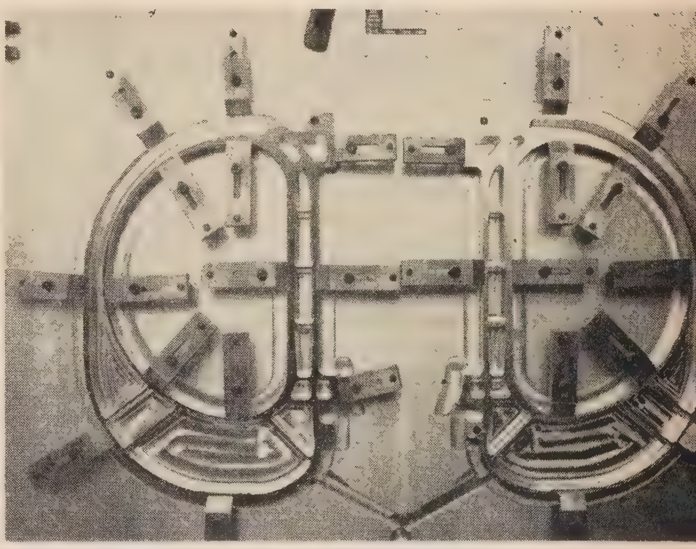
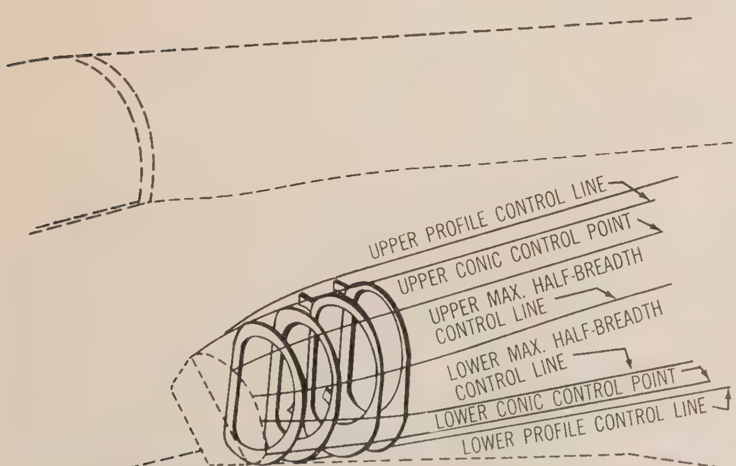
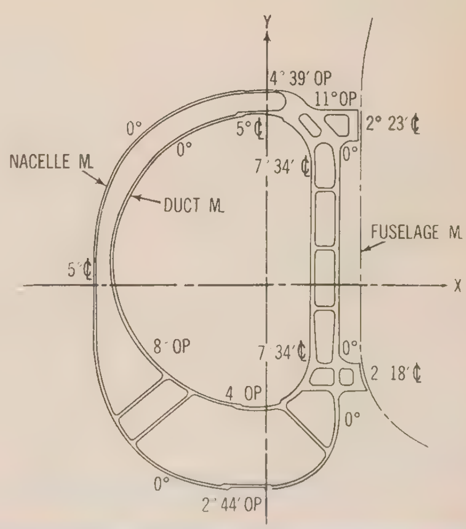


FIGURE 1: Perspective sketch of N-156F nacelle frames (below left), cross-section of nacelle frame at station 299 (below right), and nacelle frames on Kearney & Trecker profiler (above).





ANOTHER view of N-156F nacelle frames on Kearney & Trecker profiler.

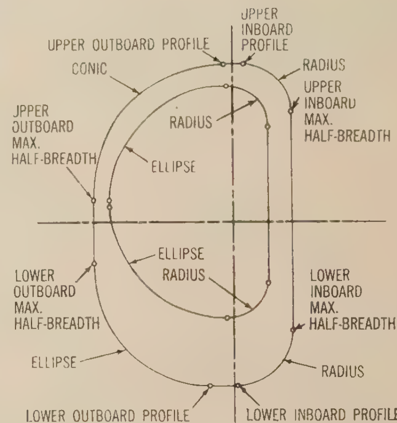


FIGURE 2: Body plan lines of nacelle frame, developed from computed data.

can now be computed, a machine control tape punched, and the fuselage templates or jig masters machined to accuracies far better than those obtained in even the most careful handwork. Often, the accepted tolerances of hand methods are cut by one half or more. And the higher accuracies —which result from the direct use of the basic dimensional data —are obtained in a fraction of the time needed for handwork.

A natural outgrowth of numerical lofting

Surprisingly enough, this type of numerical control can be done quite efficiently even with only a small general-purpose computer. The basic lines and data development group at Norair found that continuous-path numerical control is a natural outgrowth of numerical lofting. Nevertheless, it was a great day when the smaller computer was

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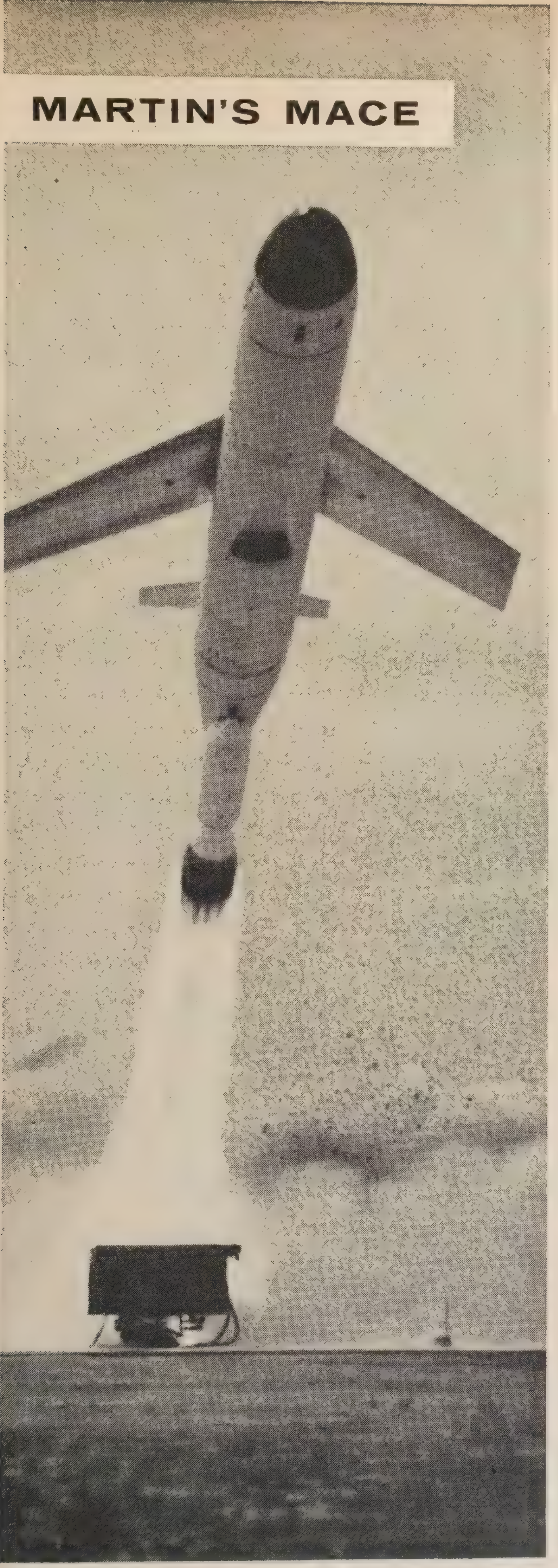
MARTIN'S MACE

Typical Equations

Nacelle, plan view, outboard maximum half-breadth (Power polynomial):

$$0.01X = 0.34701 + 0.0874887Y_1 - 0.4Y_1^2 + 0.17765239Y_1^3 + 0.60243621Y_1^4 - 3.02481974Y_1^5 + 6.00005260Y_1^6$$

Nacelle, profile view, outboard maximum half-breadth (straight line):

$$Z = -0.0788873Y + 20.55786$$

Nacelle, upper inboard radius (cubic):

$$R = 0.000007024853Y_1^3 - 0.001386145Y_1^2 + 0.085Y_1 + 0.3000$$

Typical body plan conic.

$$Z = -0.1268863X - 8.2620390 + \sqrt{-.9404746X^2 + 2.0966794X + 68.2612890}$$

replaced with a Bendix G-15D. The small computer was a fine lofting unit. However, it didn't have the storage capacity for numerical control nor could it punch a numerical-control tape.

The senior linemen and lofting mathematicians still like the flexibility of working in and out of a small computer in machine language. In this way, they get a quick check on their work and can easily correct errors and make changes in their program.

N-156F ribs are example of semi-automatic program

An outstanding example of semi-automatic programing is represented by the N-156F's fuselage and nacelle frames, or ribs. Eight ribs per airplane were machined from plate stock for the first release of the prototype aircraft. Three pairs of ribs were machined from 7075 aluminum alloy, and one pair from 4340 steel, which was heat-treated to 180,-200,000 psi after rough machining. Rough-machining before and finish-machining after heat treat were done by digital numerical tape control in a two-shift operation on three three-dimensional Kearney & Trecker profilers using Bendix control systems.

The nacelle frames support both the internal air duct skins and the external nacelle skins (*Fig. 1*). Their contours were developed by the lines group, which then took the mathematically determined contour data for both open and closed bevels, processed them through the computer, and came out with a tape to machine the parts.

Numerical control offered speed, flexibility

We chose numerical control over tracer profiling for several reasons. Engineering hadn't stabilized the design enough to justify the long hours of making tracer patterns and templates. The manufacturing schedule was so tight that we couldn't afford the long lead time needed to prepare data, templates, and patterns. Numerical control, we hoped, would shorten the lead time. Another reason was that numerical control offered the cheapest and quickest way of making engineering changes.

The lines group tackled quite a

more on page 102

Universal Fluid Coupling and Expansion Joint

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in large high pressure missile and aircraft piping installations

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- **1,200,000 life cycles without failure**
- **½ weight of bellows**
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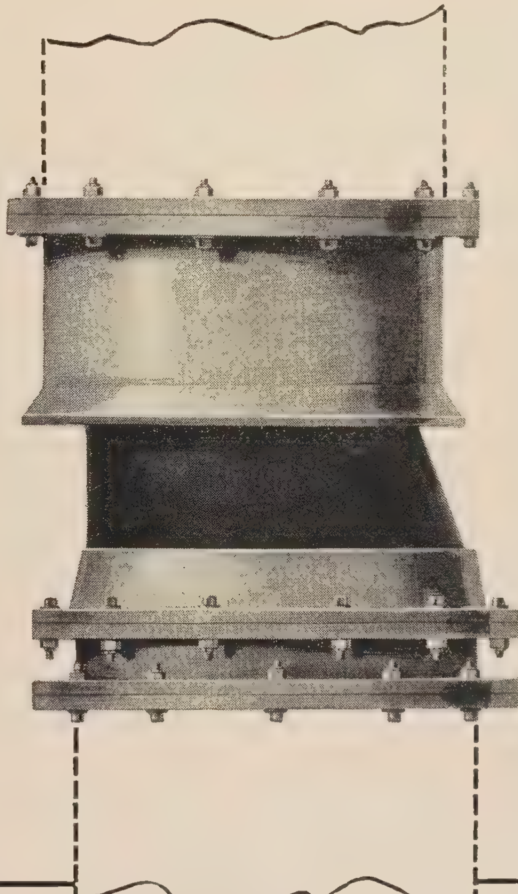
- **Smooth internal passageway**
- **No leakage**
- **Stands up to wide temperature extremes**
- **Currently used in Atlas ICBM**



An outstanding development in airborne system plumbing, Universal Fluid Couplings permit axial, angular and rotational misalignment and withstand greater lateral displacement than any bellows currently available. They have been qualified for 5″ and 9″ lines . . . and are available in line sizes from 4″ to 24″.

The Universal Fluid Coupling is typical of the advanced design and development capability of Reaction Motors—pioneer of rocket engines, missile components and ground support equipment. Capabilities include all facets of design, development and qualification tests. All phases of environmental and flow tests are performed with Reaction Motors own facilities. Wide experience in handling cryogenic, boron fuels, conventional fluids. Currently in production on huge (11″) ICBM cryogenic and conventional valves, IRBM regulators, X-15 components and valves for classified projects.

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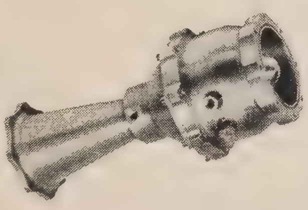
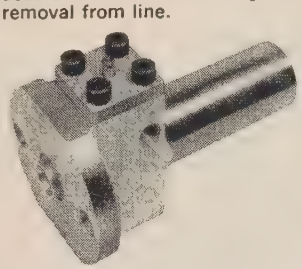


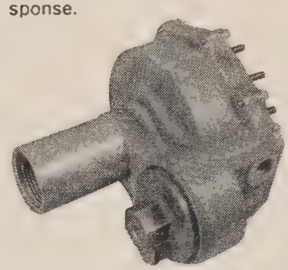
Explosive actuated on-off valve

For all liquids and gasses. Reusable without disassembly or removal from line.



Pressure regulator

For all gasses. Missile qualified, — 65°F operation, up to 3000 SCFM. High dynamic response.



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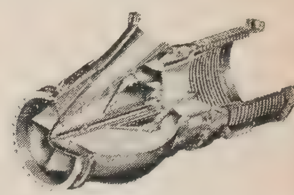

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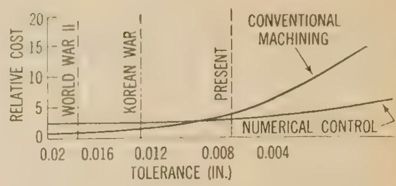
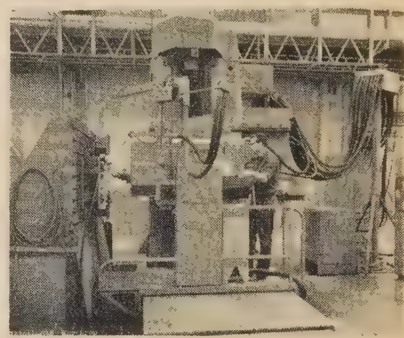


RELATIVE cost of numerical control vs decreasing machine tolerances.



DOOR PANEL for Northrop F-101 is produced on tape-controlled Kearney & Trecker milling machine.

job. It had to do a five-axis job on a three-axis, numerically controlled profiler. Not being machinists, its members also didn't know very much about metal cutting techniques or tools. However, the group did the job much faster than it could have been done by any other method and dimensionally much more accurately.

The Norair lines group uses a mathematical concept in developing the first shape of the aircraft that is expressed in rather complex equations. Once these are set, all data line layouts are obtained through the Bendix G-15D computer. By inserting a group of equations in the computer at one time, we can develop automatically the coordinates of any structural member.

Calculates coordinates on all control lines

For machined frames, this computing sequence is followed:

- The equations are loaded into the computer on prepunched tape (see *Table*).
- The computer is given instructions for the desired area and calculates coordinates on all control lines (*Fig. 3*). Enough data

more on page 104

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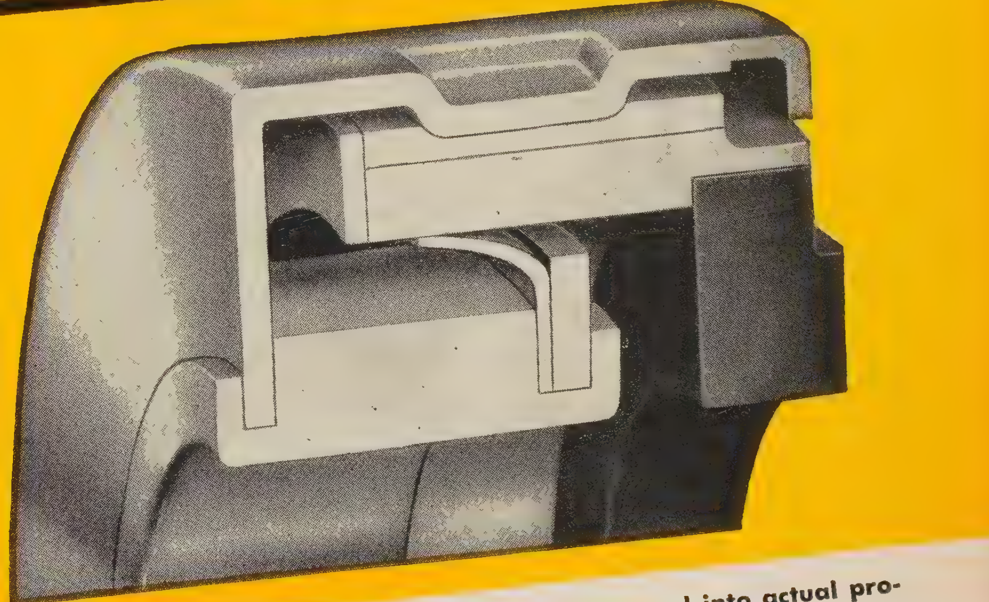

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result to develop shapes like the one in *Figure 2*.

As the contours of this shape are also the mathematical shapes of the radii or conic families, the computer is instructed to establish the appropriate formulas and determine by calculus the slopes tangent to the surface, the coordinates on the surface, and the center line of a ball-shaped cutter at predetermined increments along the periphery.

• Because the size and shape of the frames vary longitudinally, the computer is next told to duplicate the computing procedure in 0.1-in. steps for the depth of the flanges. The result is a part with correct bevels as well as the desired contour. Only minute machining marks are left by the stepping procedure.

Computer figures cutter's center path

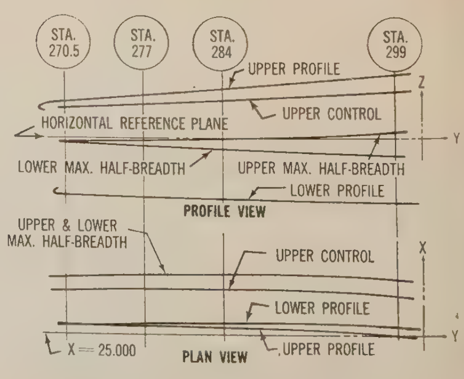
The computer calculates the cutter center path for the prescribed radius of the ball-nosed end mill. As each coordinate point is calculated, it is punched into Mylar tape in X, Y, and Z values. Feed rate and parity checks are also punched (in a code read by the tape reader at the machine tool).

This data then is interpolated into ΔX, ΔY, and ΔZ motions of the machine tool slides. The machine axes, or slides, are defined in the Cartesian coordinate system and stated in alphabetical order.

Once the X-axis has been oriented and the X-Y plane established with relation to the machine

more on page 109

FIGURE 3: Nacelle control lines, on which coordinates are computed automatically.



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If you have an applicable mission — and the need to know — you are invited to contact: Paul J. Papanek, Director of Marketing, Power Systems Group, 16555 Saticoy Street, Van Nuys, California.
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tool, the rest of the geometry falls naturally into place. The *X*-axis can be considered as the first and basic reference of the machine tool. Transformation of axes can be done at any time during the computing or tape preparing process. This becomes necessary when a *Y*-axis as it might be defined in the basic control lines of the airframe must be changed to a *Z*-axis in order to orient the part being machined with the coordinate axes of the machine tool.

Numerical control offers important savings—and not only by replacing expensive hard patterns and templates with a few feet of Mylar tape. With the same machine control tape, for instance, you can make left- and right-hand parts—by simply flipping an invert axis switch at the machine tool. (Both parts shown in *Figure 1* are machined with the same tape.) On tracer machines, two patterns are needed for machining right- and left-hand parts.

Both male or female templates can be made from the same computed data—you merely change a sign, which reverses the cutter offset from outside the male template to inside the female template. This is done during the translation or post processing part of the computing process.

Savings in product design and engineering result from the greater freedom numerical control offers to design engineers. The greater operational capacity and versatility of the new method enables designers to call for parts that previously were uneconomical to produce.

An engineering change can be made simply by splicing in a change of data in the Mylar tape. The spliced tape then can be regenerated or reproduced on a Flexowriter. In the end it results in a new tool good for machining a thousand or more parts to the requirements of the latest engineering change. And the whole change can be made in minutes or at most in hours, instead of in days and weeks.

Inventories can be kept at a minimum

Numerical control certainly is getting to be an important part of Norair's cost reduction program on the T-38 trainer and the N-156F fighter. It has cut tooling costs and lead time and raised productivity and machine use.

Since set-up time is reduced, more actual metal cutting can be done in an eight-hour day. Consistently higher productivity is insured because operator fatigue and error are becoming things of the past.

Inventories of costly replacements or spaces can be kept at a minimum, because machine set-up is so easy and you get exact duplication in machining. Accuracy from part to part and lot to lot is far better than what we get with previous methods of machining airfoil shapes.

The geometry of a part is stored permanently on the Mylar tape. It is read the same every time to the fourth decimal place, with rounding off at 0.0002 in.

Inspection also is reduced to a minimum. After the tape is proved and the first article is bought by inspection, complete physical inspection of each part is no longer necessary. Visual inspection on each part and complete physical inspection on every fifth to tenth part (according to lot size and complexity) is all that's needed.

During the computation of the cutter path, the time needed to machine the part is automatically computed, too, and typed out. It becomes a handy aid to the machine loader and scheduler.

Norair may be unique in the aerospace industry in having competitive computing systems and computers preparing tapes for numerical control. It is active in the industry-wide APT (Automatically Programed Tools) which shows great promise for realizing the full potential of numerical control (see S/A, *"Automatic Programing fits Automation to New Production Needs," Apr. '59, p. 39*).

The APT system of computer routines conceptually can be expanded to the automatic programing of cutter paths, to machine any surface defined by equations or a series, or mesh, of points. Automatic lofting or fairing of lines through points describing a surface will soon be a part of the APT sub-routine library.

Already the most conservative of all industries, the machine tool builders, are becoming the largest purchasers of tape and numerically controlled machine tools. Numeri-

more on next page

cal jig borers and point-positioning machines of all types are being offered by every tool builder in the business.

All sizes and types of machines with numerical tape control are available to the industry. At least five of the six basic arts of shaping metal are being advanced into a higher technology through numerical control—drilling and boring, turning, milling, planing, grinding, and metal forming. Only in metal forming is progress coming more slowly, because of unpredictable variables.

Numerical control is moving into the tooling industry faster than any innovation ever to hit the industry. The machine tool engineers are thinking more than ever of the stiffness or compliance of the machine tool. Machine tools are being offered with high-response, tape-controlled servo systems operating on pulse values of 25 μin. These small machines can machine or inspect a final precision part to accuracies approaching the fourth decimal place.

The aerospace industry has an ever increasing demand for higher manufacturing capabilities. The time cycle from conception to series production is getting shorter. The new exotic metals and super alloys pose tougher machining problems, requiring lower cutting speeds and more cutting tool hours per part. Some of these materials will need inerted atmospheres during machining, forming, or welding. Already we are thinking of combination units that can weld and machine on the same base.

Five-axis machines will become more common. We're already faced with the needs to "wobble tools in space." This means not only cutting tools but welding torches also must be controlled in five axes of motion or more to accuracies beyond the capabilities of human dexterity. How else can we meet these production challenges of the "space age" except by using the powerful potential of automatic computers combined with numerically controlled machine tools.—End

This special report continues on page 164, on which appears the first of four features covering electronic production and materials engineering.

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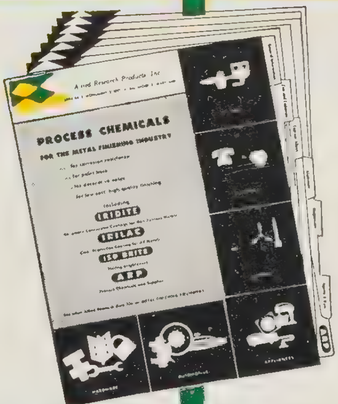

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books

Chambers Technical Dictionary, edited by C. F. Tweney & L.E.C. Hughes. This new edition contains 55,000 entries from 100 branches of technical activity, plus a 74 page supplement with 5000 more definitions of new terms. The Macmillan Co., 60 Fifth Ave., New York 11, N.Y. $7.50.

Fabrication of Molybdenum. Containing 18 papers presented at a May '58 ASM conference at Los Angeles, Calif., this covers forming, welding, protection and coating of this metal. Book Dept., American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio. $6.50.

Mathematics Dictionary, edited by Glenn James & R. C. James. Some 7000 definitions of mathematical terms, concepts and relationships are given in this revised edition. In addition, indexes give the Russian, German, French and Spanish equivalents of these terms. D. Van Nostrand Co., Inc., 120 Alexander St., Princeton, N.J. $15.

Rocket Encyclopedia, edited by J. W. Herrick & Eric Burgess. This includes definitions of rocketry terms as well as descriptions of how various systems operate, including pictures and diagrams. Also included are tables of abbreviations, symbols, engineering data, etc. Aero Publishers, Inc., 2162 Sunset Blvd., Los Angeles 26, Calif. $12.50.

Lubrication of Bearings, by E. I. Radzimovsky. This text is intended to familiarize the reader with the basic principles of bearing operation and the development and application of rational equations for bearing analysis. Examples are given of bearings construction, bearing materials and bearing analysis. The Ronald Press Co., 15 E. 26th St., New York 10, N.Y. $10.

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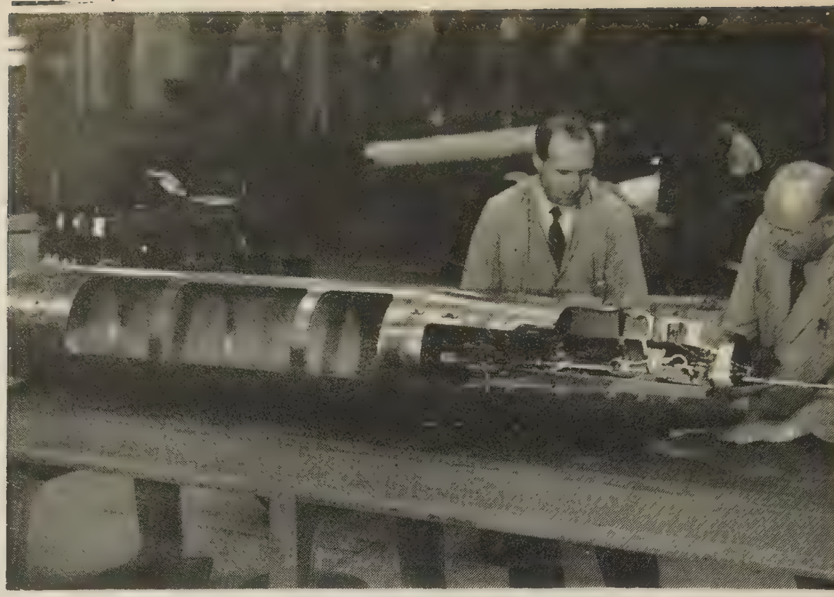
design progress

by **Randolph Hawthorne,** Editor

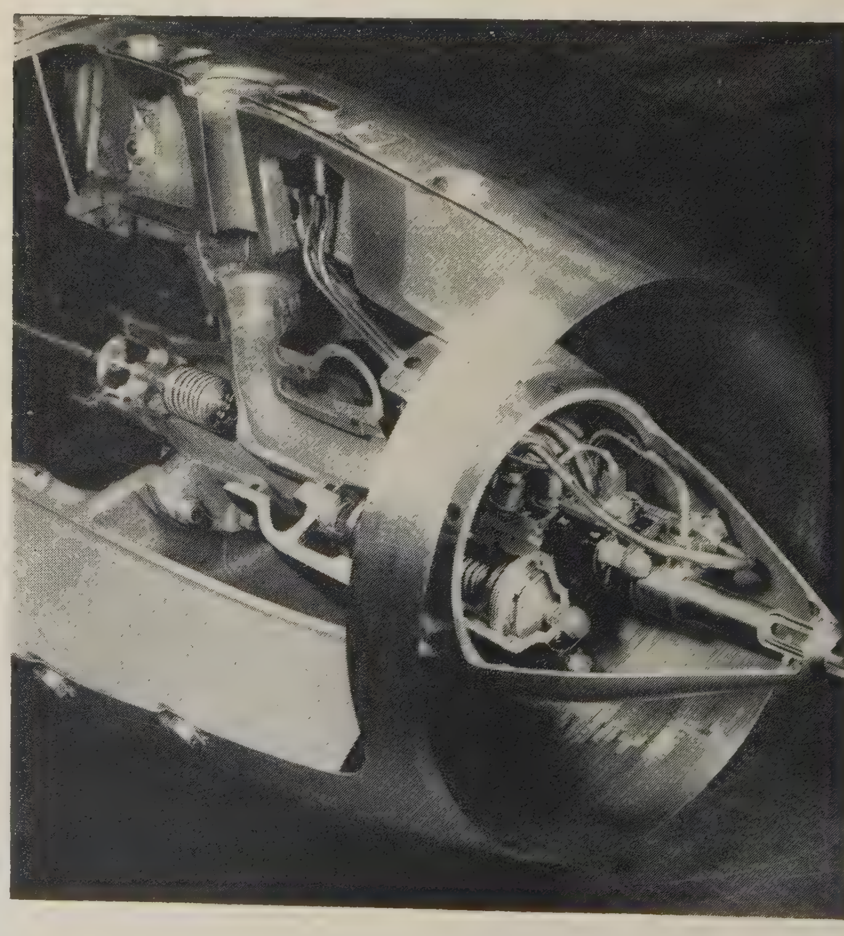
Thor ramjet develops 10,000 hp

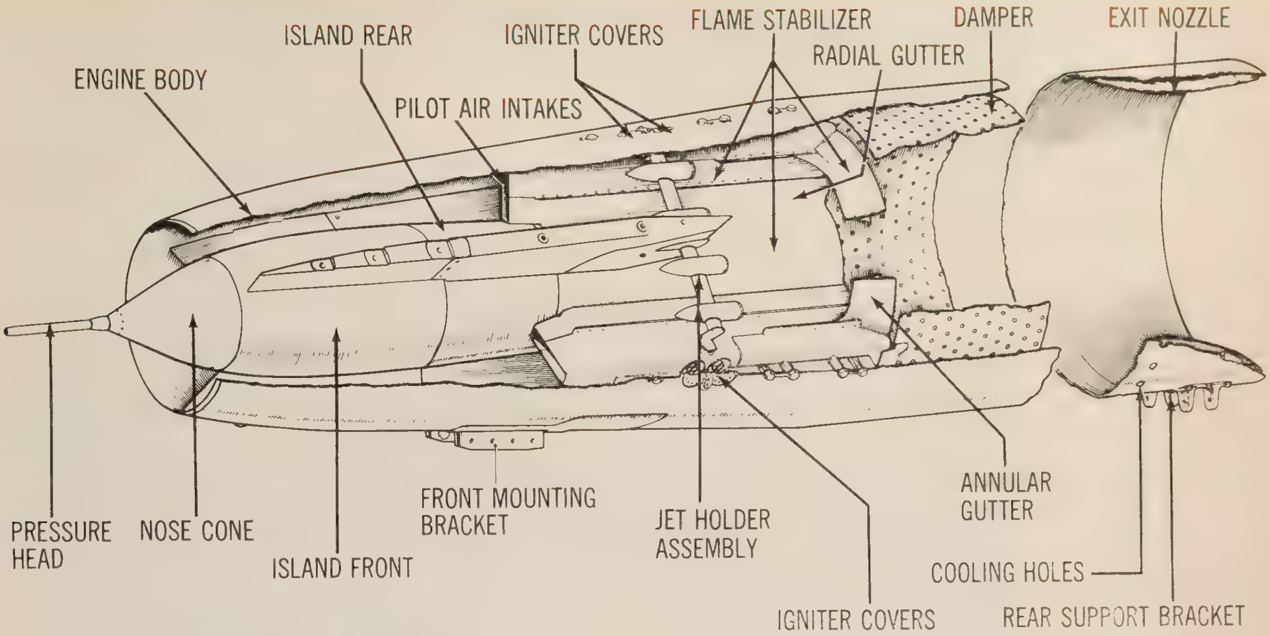
LESS than nine feet long and 1 ft. 4 in. in diameter, the Thor BT-1 ramjet develops more than 100,000 hp at Mach 3. It is an early model of the engine used in RAF's Bloodhound surface-to-air guided missile. Designed and built by Bristol Siddeley Engines Ltd., Filton, Bristol, England, the Thor is the first European production ramjet. It is designed for external pod mounting (with front and rear brackets). It was shown in cutaway form for the first time at the Society of British Aircraft Constructors Show at Farnborough in September. For further details write in No. 60 on Reader Service Card for more information.



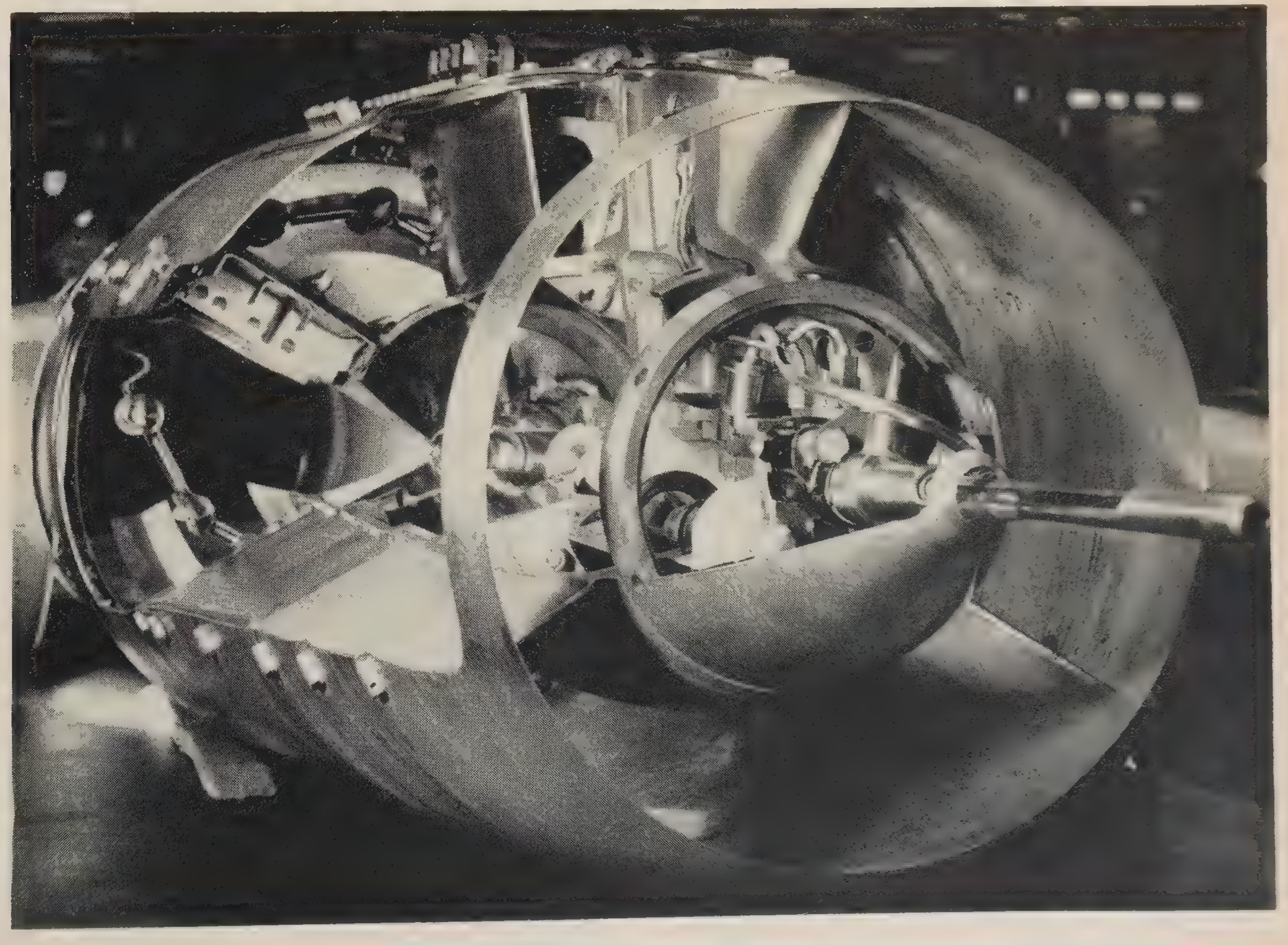
AIR ENTERING intake (right) passes around streamlined island. Fuel is burned in it in the area surrounded by the perforated damper (center). The released combustion energy causes the burning gases to travel at very high speed down the tailpipe and through the exit nozzle (extreme left), producing forward thrust.

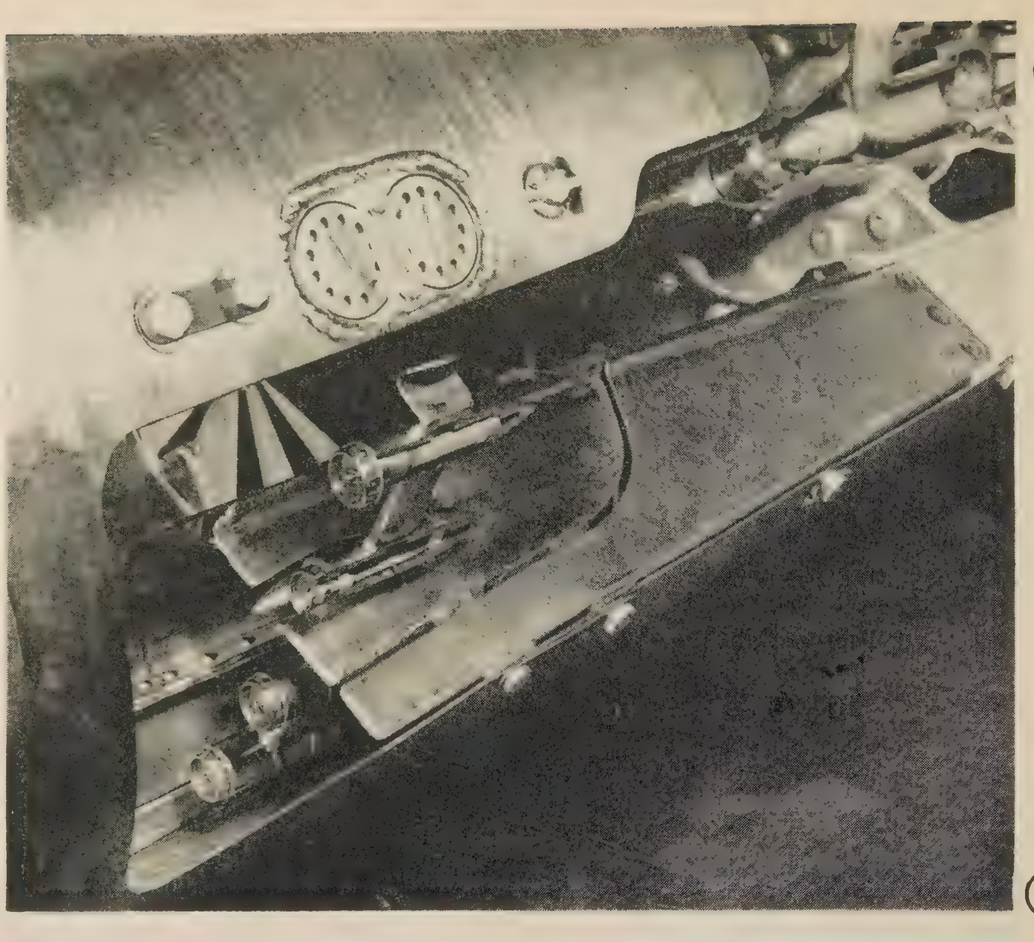
NOSE CONE and island details. The island is supported within the engine body by three vanes (top and lower left). Fuel enters through the upper vane and passes to the air-fuel ratio control (in cone), to which pressure signals are fed from the pressure head (not shown).



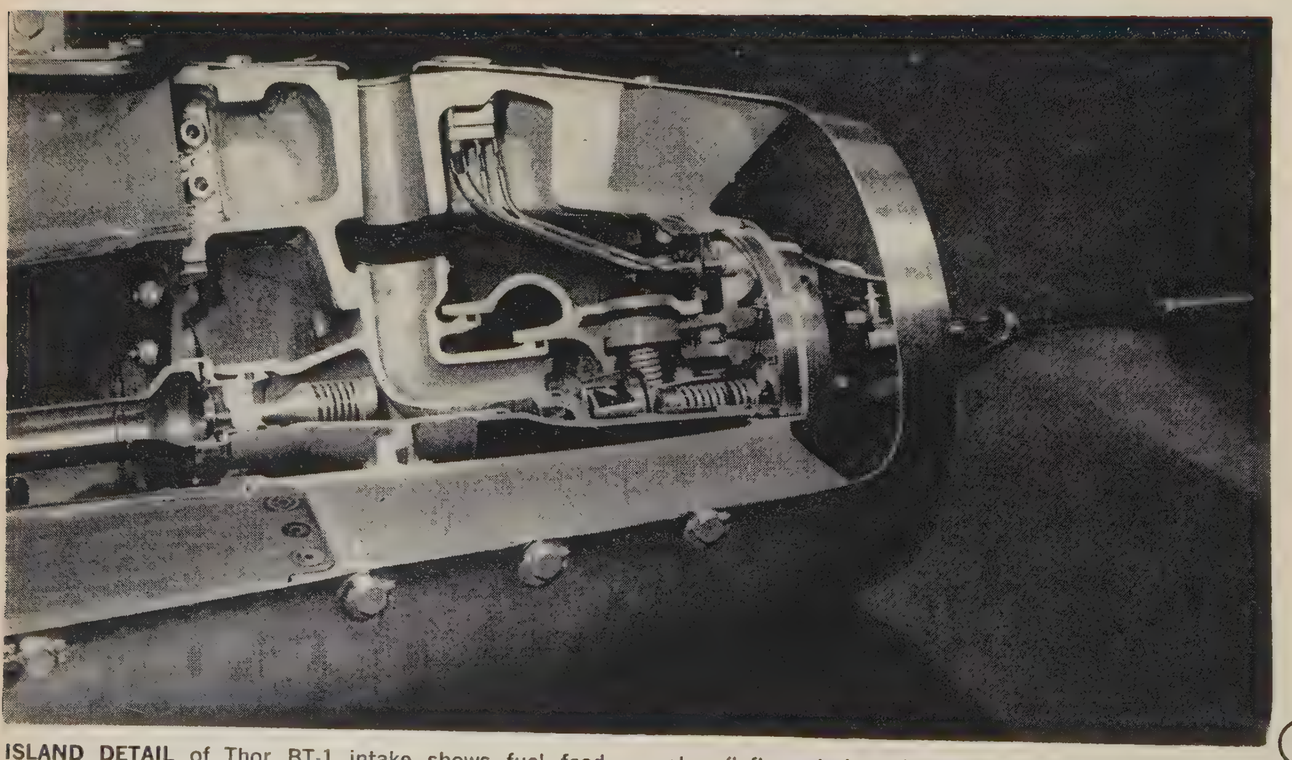


MAIN COMPONENTS of the Bristol Siddeley Thor BT-1 ramjet (above). Air enters the annular passage between the island and the engine body and is slowed down to increase the pressure. Part of it enters the pilot air intakes to provide a pilot flame. Injected through jets arranged in groups of four, the fuel burns in the wake of an annular, V-shaped "gutter," after being lit by the pilot flame. The fuel controls are housed within the island and sense the air flow conditions through the pressure head. Below: Air intake interior.





FUEL jet holder assembly. On the trailing cdge of each of three vanes, an assembly of four fuel jets is mounted. The fan-shaped device below the jets is the swirler (in the pilot combustion zone).



ISLAND DETAIL of Thor BT-1 intake shows fuel feed (top center) to the air-fuel ratio control (right), from where fuel passes around the feed elbow to a check valve (left center) and then through a tube (extreme left) to the jets. Top vane is shown with fuel feed and control pressure pipes.

How to select aerial cameras

Like any combination of highly complex mechanisms, the pairing of the right aerial camera with a vehicle for a given photo mission involves a lot of factors. This article offers a simple way of finding the parameters that you want to consider before deciding on what camera to use.

by Samuel Bousky, Chief Scientist, Chicago Aerial Industries, Inc.

AERIAL PHOTOGRAPHY is a highly complex business. Nevertheless, you can acquire enough of a working knowledge of aerial photography to be able to find the important factors for any given camera installation and to evaluate the trade-offs involved in a first-order optimization.

Because of space limitations, our discussion here of the factors in the selection of aerial cameras necessarily must use certain simplifications, approximations, and empirical relationships. Above all, we'll consider only the simple case of a single, conventional, vertically mounted camera operated in level flight.

All the parameters controlling the selection of aerial cameras are functions of either the target, the vehicle, or the camera itself. The parameters that depend primarily on the target or the target area are brightness, contrast, coverage, and definition. (For the sake of brevity, we will from here on use the term "target" for both point and area targets.)

Brightness is the value of the light reflected from the target and is measured in foot-lamberts. In aerial photography, it normally ranges from about 100 to 1000 foot-lamberts.

Contrast is the brightness ratio of light to dark in the target and is expressed as the common logarithm of this ratio. In actual targets and with recording film processed to a gamma of 1.4, it normally ranges from the recording threshold of about 0.025 to about 0.3 at high altitude and about 1 at low altitude under favorable conditions. In computations, 0.1 at high altitude and 0.3 at low altitude can be used as mean values.

Coverage is the distance on the ground that is spanned by the camera. "Lateral" coverage refers to distances normal to the flight direction and is measured in feet; "forward" coverage refers to distances along the line of flight and is measured in nautical miles.

Definition is the smallest target dimension that can be spotted on the photograph and is measured in linear feet. There are two types of definition—"detectable" and "recognizable." We will concern ourselves only with the latter, which is invariably the larger.

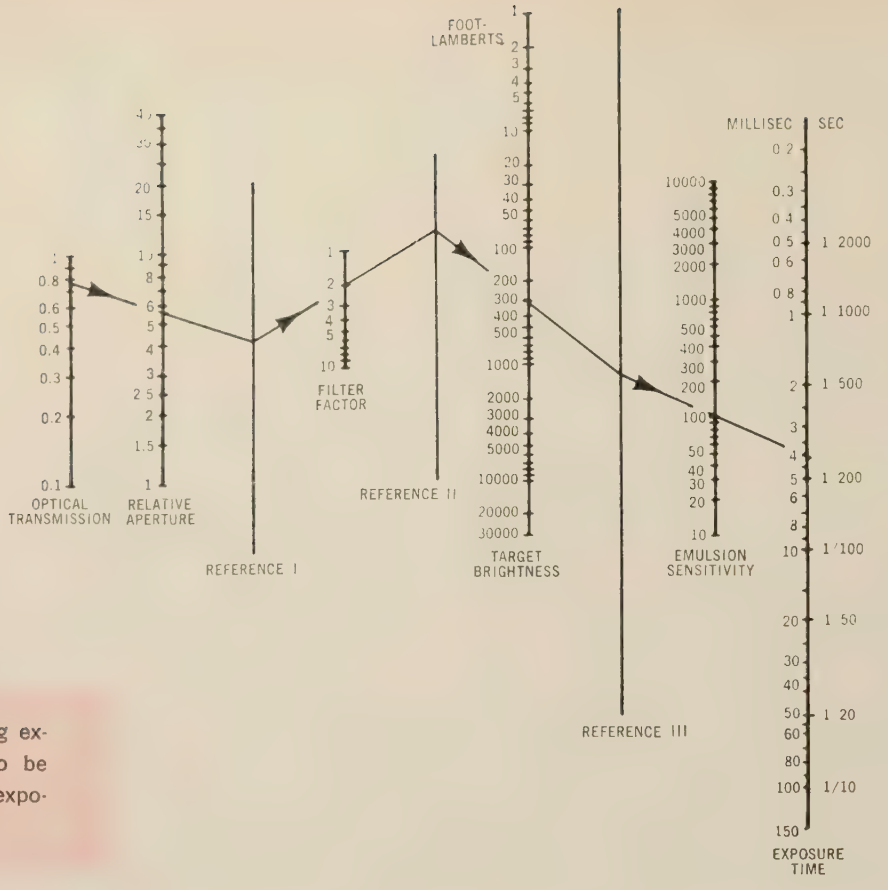
The parameters that depend primarily on the vehicle and its flight are speed, altitude, drift, rotational instability, vibration characteristic, and photo mission distance.

Speed is simply the groundspeed, measured in knots or feet per second.

Altitude is the distance above the ground and is measured in feet. The speed altitude ratio (V/H), too, is an important parameter of aerial photography; also known as *angular image rate*, it is expressed in knots per foot or radians per second.

more on next page

* Chicago Aerial Industries, Inc., 1980 Hawthorne Ave., Melrose Park, Ill.



1 Nomograph for finding exposure time. It can also be worked backwards from exposure to yield brightness.

Drift is the angular difference between heading and bearing and is measured in degrees.

Rotational instability covers the roll, pitch, and yaw deviations from straight-line flight. For our purposes, we need consider only the nominally peak roll and pitch rates, expressed in radians per second.

The *vibration characteristic* can be neglected in our discussion, since vibration effects are readily controllable for any installation such as we are discussing.

Photo mission distance is the total linear ground distance over which photographic operation is required. It equals the total forward coverage and is also measured in nautical miles.

The parameters that depend primarily on the camera and its installation and accessories include format dimension, depression angle, focal length, relative aperture, optical transmission, filter factor, image motion compensation, cycling rate, exposure time, film supply and type, and emulsion sensitivity.

The *format dimensions* are the length and width of the camera opening in the focal plane. In effect, therefore, they are also the frame dimensions. Depending on how the camera is mounted with respect to the line of flight, these two dimensions are known as "lateral" and "forward." Their standard values are 2.25, 4.5, nine, and 18 in.

The *depression angle* defines the camera's mounting position with respect to a horizontal plane and is the angle formed by the optical axis with this plane. Since we are here dealing only with a vertically mounted camera, this angle is 90 deg throughout our discussion, and we don't have to consider it any further.

Focal length is the effective optical focal length of the lens in the camera and is measured in inches.

Relative aperture is the ratio of focal length to lens aperture and is often used to indicate lens "speed." It is expressed in f/stop numbers.

Optical transmission is the effective transmission of the camera lens and is expressed either as a percentage or as a decimal value. When its value is unknown, 85 per cent, or 0.85, is often used as a reasonable approximation for the average coated lens.

Filter factor is the numerical factor by which the exposure must be increased to compensate for the losses due to the use of a camera filter. For Aerographic Super XX (Class L) film, a K2 yellow filter has a factor of 2 and an A25 red filter a factor of 4.

Image motion compensation (*IMC*) is the velocity at which the film in the camera is moved during exposure as it is synchronized with the forward movement of the image. It is measured in inches per second. In choosing cameras using IMC, both the minimum and the maximum values of this parameter should be determined.

Cycling rate is the rate at which exposures are made and pictures taken. It is expressed as frames per second. In considering a camera with which successive cyclic exposures are to be made, the maximum cycling rate must be determined. In our discussion, the cycling rates are based on 60 per cent image overlap from one picture to the next.

Exposure time is the period during which the film is effectively exposed to the image and is expressed in milliseconds or unity-numerator fractional seconds.

The *film supply* is the length of film on the supply

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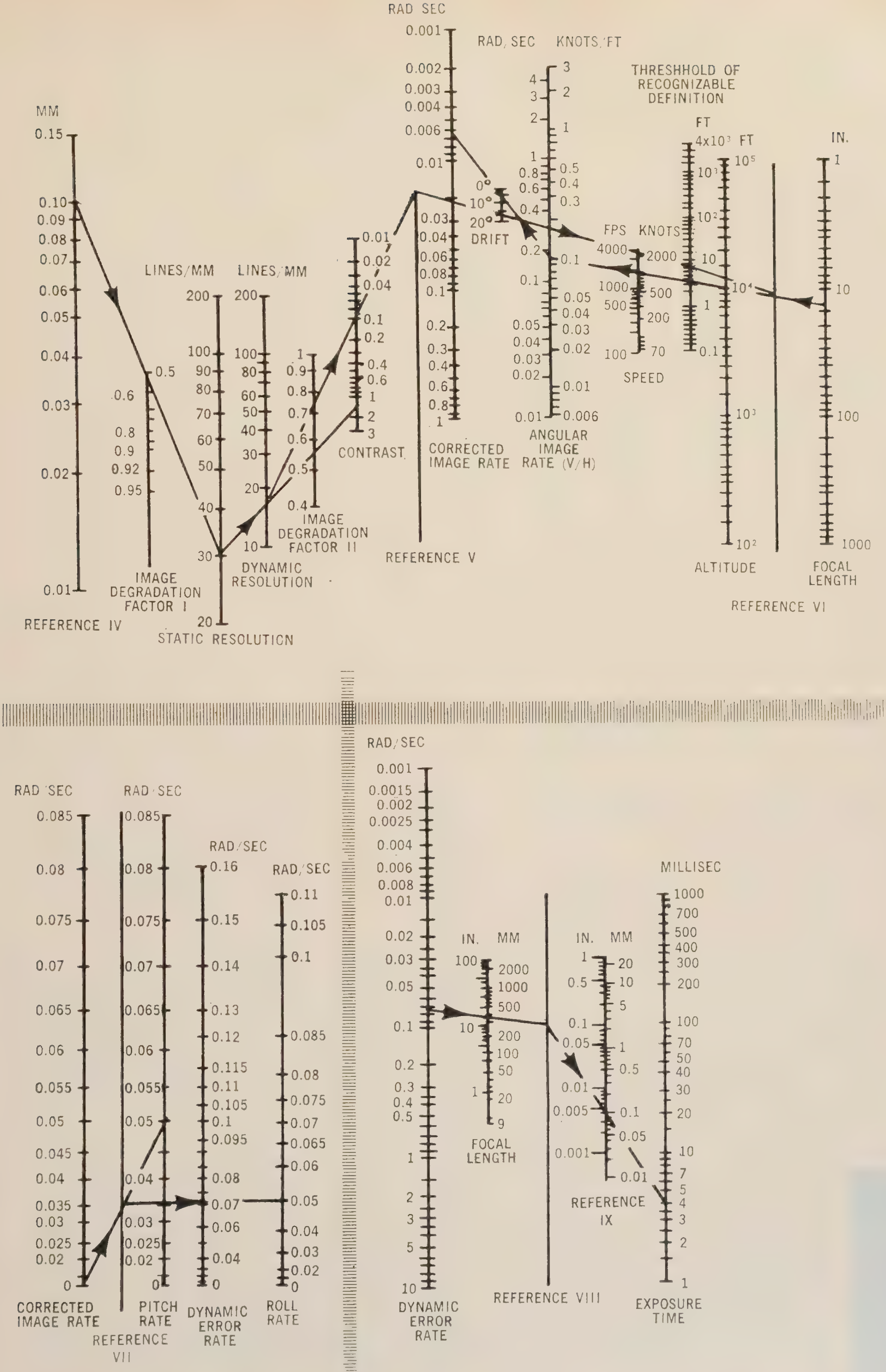
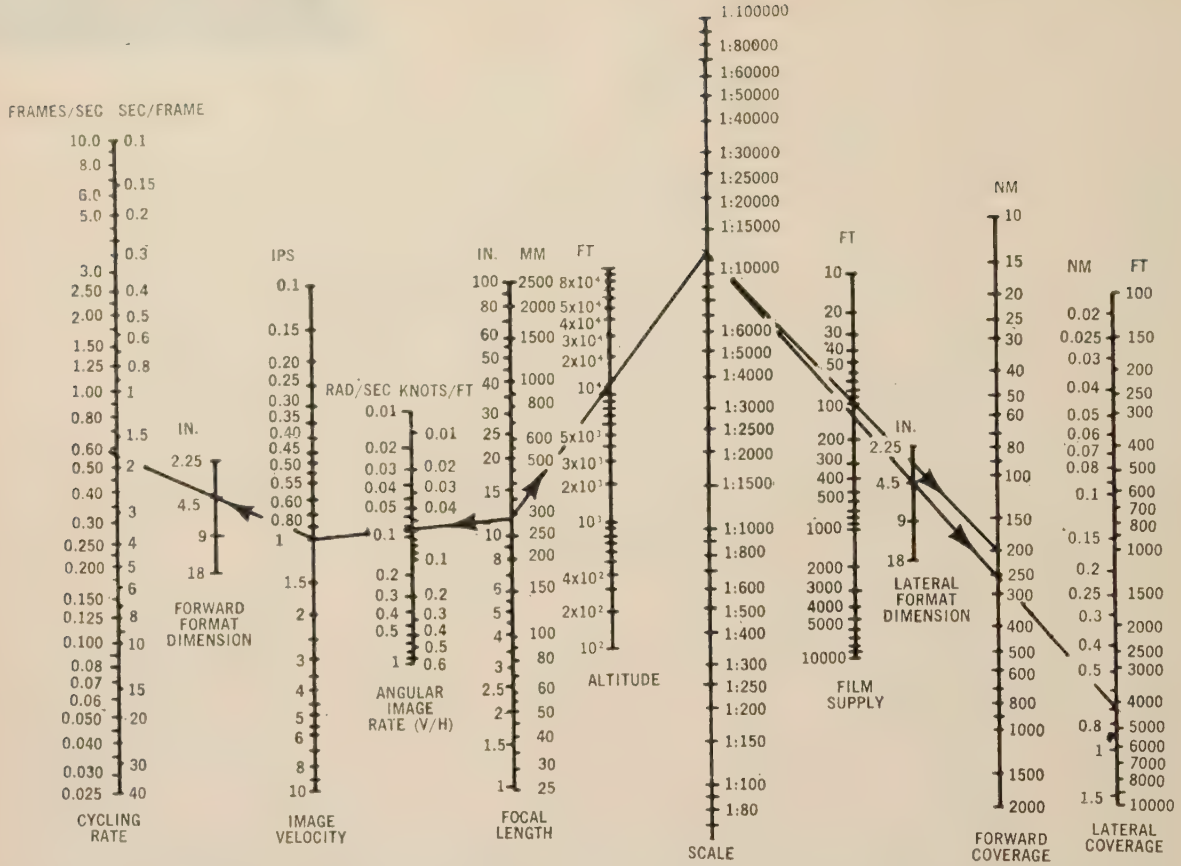


2 Nomograph for finding target definition. It can be used for installations with or without image motion compensation.

Nomograph for finding the operational factors of image velocity, cycling rate, scale, and forward and lateral coverage.

3



spool in the camera (or the magazine or cassette) and is measured in feet. Standard military lengths are 100, 250, 500, and 1000 ft.

Film type refers to the class of the film used in the camera. We are restricting our discussion to Class L film (Aerographic Super XX or equivalent) exposed and processed to a gamma of 1.4.

Emulsion sensitivity is the ASA rating of the film. For Class L film, it is 100.

Evaluating all these camera selection parameters by computation is a tedious business. Much time therefore can be saved by the use of nomographs yielding exposure time, target definition and certain basic operational factors.

Figure 1 shows a nomograph for exposure time. This parameter depends on optical transmission, relative aperture, filter factor, target brightness, and emulsion sensitivity. If no reasonably exact value is known for any of these parameters, an approximation may be made, or two extremes may be determined and the problem solved for both. When no filter is used, the filter factor is taken as 1.

This nomograph is used as follows:

- Draw a straight line from the value for optical transmission to that for the relative aperture and continue to Reference Line I.
- From the intersection with that Reference Line, draw a straight line through the value of the filter factor and continue to Reference Line II.
- From the intersection with this Reference Line, draw a straight line through the brightness value and continue to Reference Line III.
- From the intersection with this Reference Line, draw a straight line through the value for emulsion sensitivity and continue to the last scale, on which you then read the exposure time.

Figure 1 shows a sample problem assuming the following values: optical transmission, 0.785; relative aperture, f/5.6; filter factor, 2; brightness, 300 foot-lamberts. The exposure time for these values is found to be four milliseconds, or 1/250 second.

New brightness value can be found

If for some reason you need a shorter exposure time than the one indicated by this nomograph, you could use the nomograph to find the corresponding new brightness value. You repeat the operation we have just described until you have the intersection on Reference Line II. Then, starting at the exposure-time scale, you work backward and find the proper value on the brightness scale.

Figure 2 shows a nomograph for the determination of target definition. This parameter depends on many factors, including speed, altitude, focal length, static resolution, contrast, drift, pitch rate, roll rate, and exposure time. The nomograph is used as follows:

- Start from the value of focal length in *Section A* of the nomograph and draw a straight line to the altitude value, intersecting Reference Line VI.
- Draw a straight line from the altitude value through the speed value and continue to the next scale, which gives the angular image rate (V/H). Now your next step depends on whether IMC is used or not.

• If IMC is used, draw a straight line from the value of V/H through the drift value and continue to the next scale, which gives the corrected image rate. (If there is drift correction, too, this line should be drawn through zero on the drift scale.) Transfer the corrected image-rate value to the first scale in *Section B*. (For convenience, the numerical values in *Section B* may be multiplied by 10^n—so long as they are *all* multiplied by the same factor.)

• If there is no IMC, transfer the uncorrected V/H value from *Section A* to the first scale of *Section B*. (We can neglect the drift in this case.)

• From the value of image rate set in on the first scale of *Section B*, draw a straight line to the value of the pitch rate, intersecting Reference Line VII. (The pitch rates of the average high performance aircraft during photographic operation may range from about 0.05 to 0.2 rad/sec. In highly stabilized vehicles, it may be as low as 0.01 rad/sec.)

• From the intersection on Reference Line VII, draw a straight line to the value of the roll rate and read the dynamic error rate on the next-to-last scale. (The roll rate of the average high performance aircraft during photographic operation may range from 0.1 to 0.3 rad/sec. In highly stabilized vehicles, it may be as low as 0.01 rad/sec.)

• Transfer the dynamic error rate from *Section B* to the first scale of *Section C*.

• From the value of the dynamic error rate as set in on the first scale of *Section C*, draw a straight line through the value of focal length and continue to Reference Line VIII.

• From the intersection on this Reference Line, draw a straight line to the value of exposure time, intersecting Reference Line IX.

• Read the value at the intersection on Reference Line IX and transfer it to Reference Line IV in *Section A*.

• From the value on Reference Line IV, draw a straight line to the value of static resolution, intersecting the first image-degradation-factor scale. (The static resolution is equivalent to the bench-tested resolution. For the lens-film combination we are considering, it usually ranges from 10 to 50 lines per millimeter for Class L film.)

• Transfer the value just established on the first image-degradation-factor scale to the second image-degradation-factor scale farther to the right.

• Draw a straight line from the value of static resolution to the value entered on the second image degradation-factor scale, intersecting the dynamic-resolution scale.

• From the intersection on the dynamic-resolution scale, draw a straight line through the value of contrast and continue to Reference Line V.

• From the intersection on this Reference Line, draw a straight line to the intersection on Reference Line VI established at the beginning of the operation. This straight line intersects the definition scale and gives you the recognizable definition for the threshold ground target.

The sample problem shown in *Figure 2* assumes the following conditions: speed, 1000 knots; altitude, 10,000 ft; focal length, 12 in.; static resolution, 30 lines per millimeter; contrast, 0.1; drift, five degrees; pitch rate, 0.05 rad/sec; roll rate, 0.05 rad/sec; exposure, four milliseconds. For these values, the nomograph yields a target definition of 6.5 ft with IMC.

Like all the results obtainable from the nomographs shown here, the target definition yielded by *Figure 2* applies only to Class L film. However, you can make approximations for Tri-X and Aerecon Plus-X film—use the nomograph of *Figure 2* and, respectively, multiply or divide the result by 1.4.

Figure 3 shows a nomograph for the determination of a series of operational factors—image velocity, cycling rate, scale, and lateral and forward coverage. These factors depend on focal length, altitude, angular image rate, format dimensions, and film supply. The nomograph is used as follows:

• Draw a straight line from the value of focal length through the value of the angular image rate (V/H) and continue to the image-velocity scale, which gives you the first of the factors you are looking for. (V/H, as we have seen, can be found from the nomograph of *Figure 2*.)

• From the value of image velocity draw a straight line through the value of the forward format dimension and continue to the cycling-rate scale, which gives you the second of the desired factors.

• Go back to the value of focal length and draw a straight line from it through the value of altitude and continue to the "scale" scale, finding the third desired factor.

• From the value of scale, draw a straight line through the value of the lateral format dimension and continue to the lateral-coverage scale, which gives you another desired factor.

• Again from the value of scale, draw a straight line through the value of film supply and continue to the forward-coverage scale, which gives you the last of the desired operational factors.

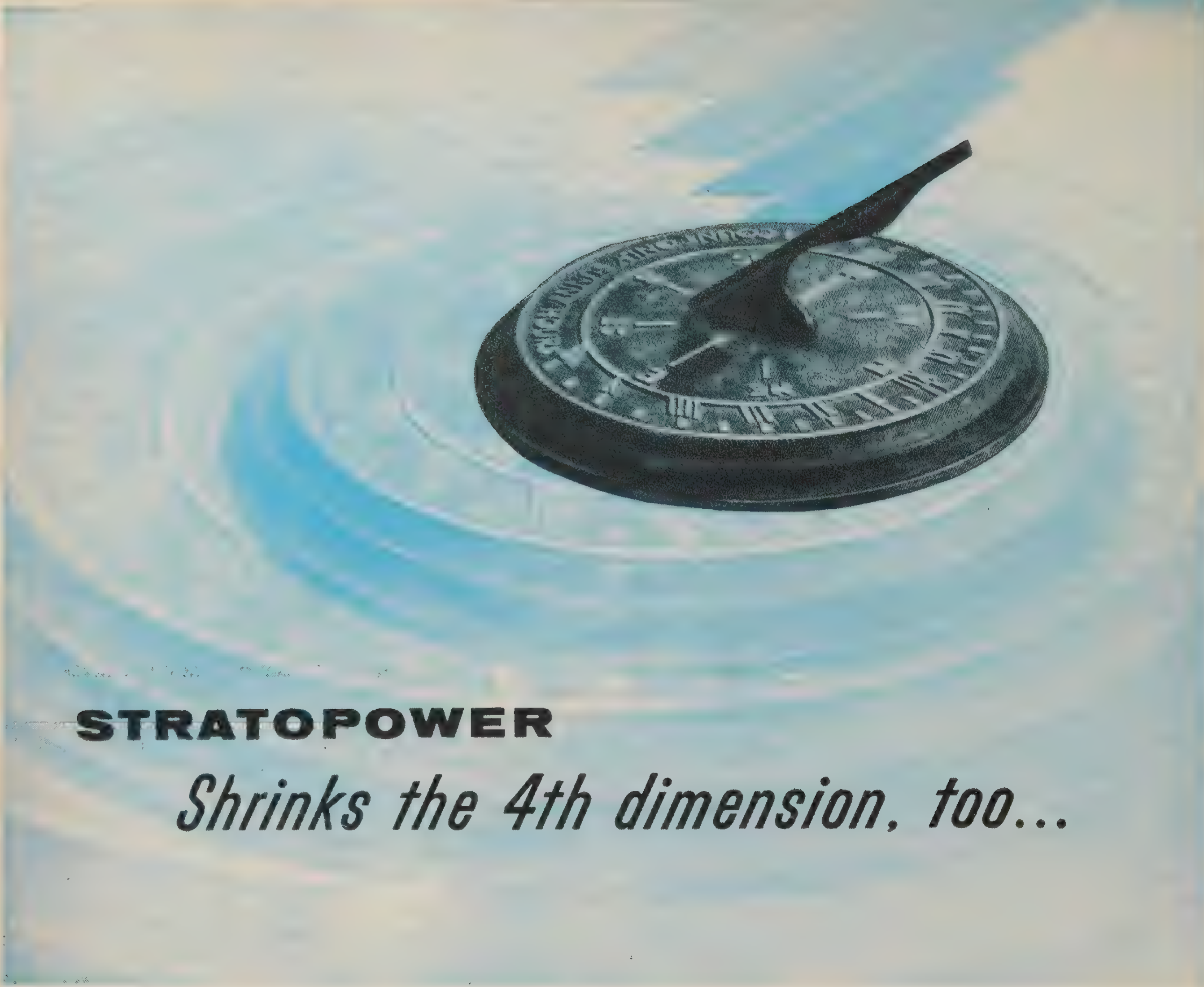
The sample problem shown in *Figure 3* assumes the following values: focal length, 12 in.; altitude, 12,000 ft; angular image rate, 0.085 rad/sec; format dimensions, 4.5x4.5 in.; film supply, 100 ft. The corresponding operational factors are found to be: image velocity, one ips; cycling rate, 1.8 seconds per frame; scale, 1: 12,000; lateral coverage, 4500 ft; forward coverage, 80 nm.

Film supply, altitude also found

This nomograph, too, can be worked backward under certain circumstances. For instance, assume the mission to which the sample problem applies requires a forward coverage of 175 nm rather than 80 nm. You can draw a straight line from 175 nm on the forward-coverage scale to the value of scale and find that now about 220 ft of film supply are needed.

Or assume the camera you are considering cannot cycle faster than at two seconds per frame. You can start from this value on the cycling-rate scale and work back through the original value of forward format dimension to a new value of image velocity. From there, you can go on through the original value of focal length and find a new value for V/H. This value can be transferred to *Section A* of the nomograph in *Figure 2*. Going on from there through the known value of speed, you can get a new value for altitude, compatible with the cycling rate.

A worth-while approximation can be made for Tri-X film that is rated at ASA 200 and whose static resolution is known: The nomographs will give you a rough idea of what you may gain or lose through the shorter exposure time possible with this particular film.—End



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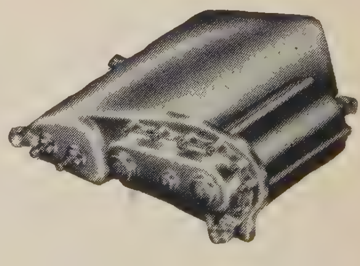

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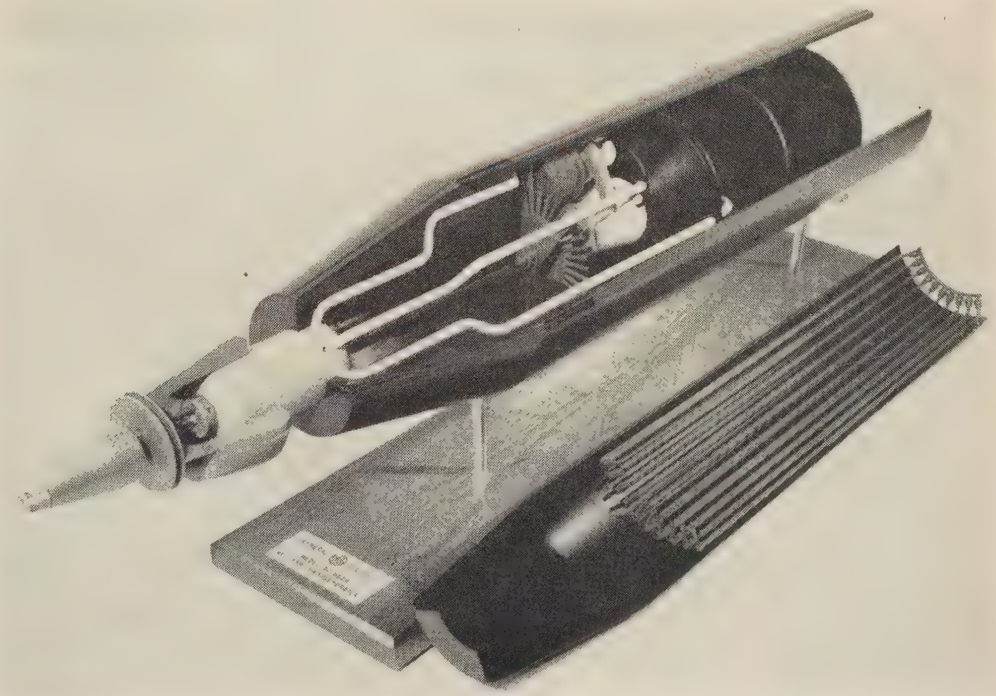

ALKALI-METAL two-phase, one-megawatt electric power supply for future space missions was proposed by GE engineers M. A. Zipkin and Erwin Schnetzer. Seventy feet long, the unit would include a nuclear heat source, a boiler, and a turbine-alternator.

IAF congress highlights:

man in space, exotic propulsion, APUs

As in past years, the papers and discussions at the recent annual IAF congress gave a capsule review of the state of the art in space flight. Here is a report on this important technical meeting by S/A editor Kurt Stehling, who was a member of the U.S. delegation.

by Kurt R. Stehling,
Contributing Technical Editor

THIS YEAR'S International Astronautical Congress, held recently in London under the auspices of the British Interplanetary Society, set an attendance record —over 500 "astronauts" from all over the world came to the Congress. There was no single subject that predominated in London, as had been the case two years ago in Barcelona, when Sputnik I went up just in time for the Congress. However, several areas of special interest were clearly apparent—the Mercury program, exotic propulsion, and APUs.

The keynote speech at the Congress was given by Dr. Hugh L. Dryden, NASA's deputy administrator, on "Global Aspects of Space Exploration." In the course of

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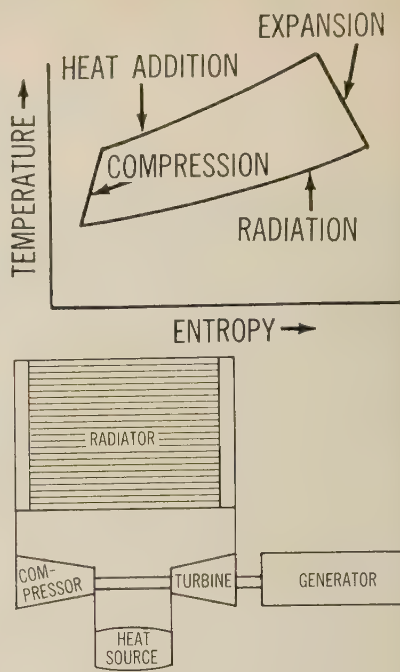

CYCLE diagram and schematic of an inert-gas power supply as described by Zipkin and Schnetzer. Gaseous helium is compressed by an axial-flow compressor; heat is then added at constant pressure; the gases are expanded through a turbo generator; and the waste heat is rejected in a radiator at continuously decreasing temperature.

a detailed review of past and present space flight efforts, Dr. Dryden pointed out that Australian, British, French, Japanese, Soviet, and U.S. scientists all are collaborating in the current high altitude sounding program. Turning to future projects, he laid particular stress on the Scout space vehicle as an example of a relatively cheap and easily launched design. He pointed out that such vehicles can be used for many space science programs and, above all, are suitable for countries without extensive launch facilities.

On the Mercury project for launching a man into space, Dr. Dryden said that about $200 million would be needed merely to get Mercury to its *first* objective, the orbiting of a manned capsule. Throughout his speech, he emphasized the need for international cooperation in non-military scientific space studies, as on meteorology and climatology.

A considerable number of papers gave more details on the problems of manned space flight. Capt. Ash-

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TAPEnology cuts jet's roar to hushed whisper

When Convair's new 880 "Jet-Liners" go into scheduled airline service early next year, high frequency noises of the boundary-layer effect and the exhaust from the four powerful General Electric CJ-805 turbo-jet engines—somewhat suppressed by extra-thick fuselage skins—will be further hushed to a soft whisper inside the cabin by a newly developed "SCOTCH" Brand Tape.

More than 1¼ miles of this tape—"SCOTCH" Brand No. 428 Sound Damping Tape—is applied directly to inside of fuselage panels throughout the "880". A specially developed visco-elastic adhesive between the tape backing and the skin panel reduces metal vibration by converting sound energy into heat energy . . . changes the natural frequency of the panel . . . provides sound damping beyond that possible only by adding either mass or stiffness to the aluminum. One person can do entire application if necessary . . . weight control is precise throughout. Results? "Beyond expectations of acoustic engineers" says Convair.

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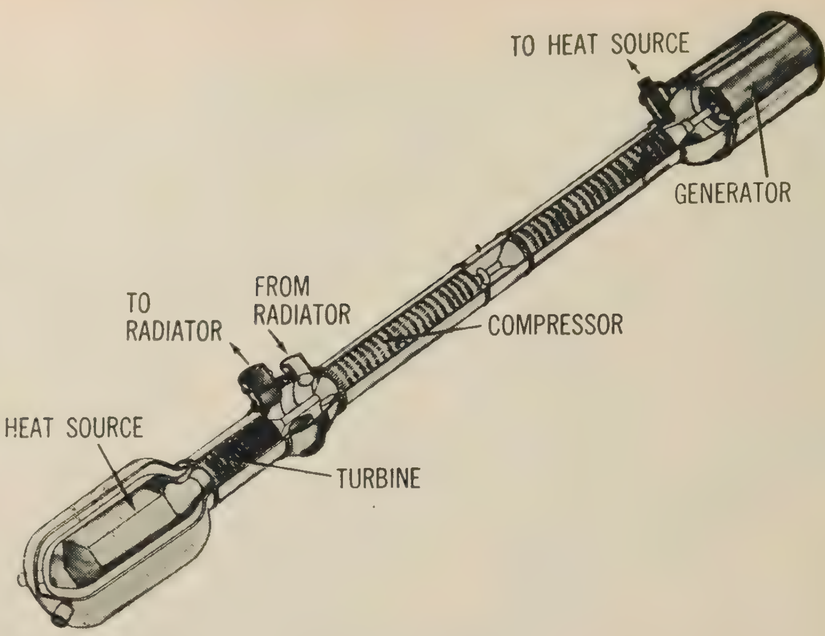

CONFIGURATION of an inert-gas one-megawatt power supply as given by Zipkin and Schnetzer. The unit would have a rotative speed of 24,000 rpm and use helium as its working fluid. The compressor would have 41 stages, a pressure ratio of 3.6, and a weight flow of 4.3 pps; the turbine would have 12 stages, an inlet temperature of 2140 deg F, and a pressure ratio of 3.

ton Graybiel, of the U.S. Navy's Medical Corps, and two co-authors described the effects of ballistic-missile flights on monkeys in "Observations on Small Primates in Space Flight." The monkeys survived flights in Redstones and Jupiters (including re-entry), showing only relatively insignificant physiological changes. There appeared to be no damage to the bodies of the monkeys nor any permanent heart difficulties.

The authors also pointed out that at present the data obtainable from monkey tests such as they described are not in proportion to the effort that must be invested in the tests. Above all, they were not able to measure the monkeys' performance under test—they could only measure physiological conditions. They expressed the hope that true performance tests would become possible in the future.

Highly interesting was the paper on "The Prediction of Man's Performance in Space Using Flight Simulators and Balloon-Borne Systems," by J. Gordon Vaeth, of ARPA's Man-in-Space staff. Vaeth showed that much worth-while research on manned space flight can be done cheaply with high altitude balloon capsules, which offer a true closed system. He admitted that zero gravity cannot be simulated in balloon capsules but pointed out that otherwise 90 per cent of the operating conditions of a space capsule can be duplicated.

This year, U.S. authors were in the forefront of the Congress's discussions of electric and nuclear propulsion. Papers on magnetohydrodynamics and magnetic plasma propulsion were given by R. Meyer, of Space Technology Labs, Ralph Waniek, of Giannini, and A. Kantrowitz, of Avco. These authors again demonstrated that plasma propulsion is technically feasible but warned that critical problems remain to be overcome.

It was also pointed out that even propulsion people sometimes have trouble distinguishing between ion propulsion, nuclear propulsion, plasma propulsion, and photon propulsion. In plasma propulsion, the molecules or atoms of a very highly ionized gas are virtually torn apart by the electric and magnetic effects in an electric arc or some other device producing high temperatures.

The most critical problems of plasma propulsion are the production of the ionized gas and especially the containment of the gas in a thrust-producing vessel. The ionized and un-ionized gases (say,

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Wright Servo Motors With Inertia Damping Eliminate Need For Tachometer Generator

These new Wright-designed motors eliminate the need in high response systems for tachometer generator feed-back. They have built-in damping to resist sharp acceleration or deceleration. They provide stabilization through reversible viscous torque which has no effect at constant speed, and only minute effect on small incremental changes in velocity.

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THANKS TO Alcoa's pioneering with the metallurgical technique known as "dispersion hardening," solid aluminum products reformed from *powdered* aluminum by heat and pressure take on new qualities. They are fine-grained, hard, tough, sapphire-like in brilliance, and amazingly resistant to heat effects.

ALUMINUM POWDER metallurgy products—"APMP" for short—are available in a family of four alloys. They are usually extruded into forms which can subsequently be further extruded, rolled, forged, drawn or impacted by conventional metal-working methods. Where you need the properties of aluminum, but where temperatures seem "too high" for conventional aluminum products, chances are that one of these four alloys may solve a host of hectic problems.

NATURALLY, there's more to the story than we've been able to pack into this limited space. If you'd like to know more, please write for our free booklet, *Alcoa's Aluminum Powder Metallurgy (APM) Alloys.* Aluminum Company of America, 2027-L Alcoa Building, Pittsburgh 19, Pennsylvania.

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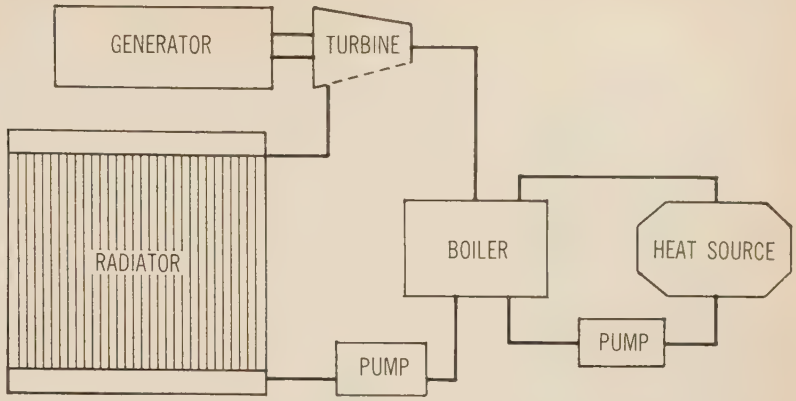

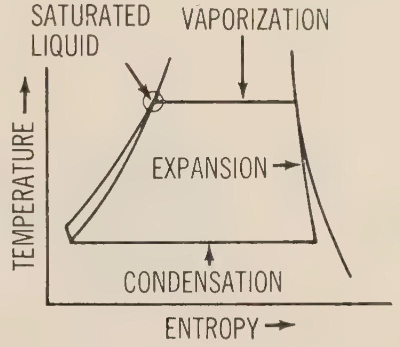

CYCLE diagram and schematic of a power supply using vaporized liquid metal and also proposed by Zipkin and Schnetzer. Heat is added at constant pressure in the boiler until the metal is in a saturated liquid condition; the liquid is then vaporized at constant temperature and pressure; the vapor is expanded through the turbine; and the wet vapor is condensed at essentially constant pressure and temperature in the radiator.

nitrogen, oxygen, and hydrogen) tend to recombine in such a vessel. Also, their intrinsically high temperatures release extra heat. Under these circumstances, heat transfer turns into such a headache that the authors of the papers at the London Congress as well as other researchers have proposed that the plasma should be contained, or "pinched", magnetically—the gases would not go beyond an invisible containing magnetic field and actually never touch the vessel's walls.

In a progress report on ion propulsion work at Rocketdyne, R. H. Boden declared that it will take another few years before we have an ion device producing more than a pound or so of thrust while meeting the tight volume requirements of a space vehicle. However, he also pointed out that Rocketdyne has licked many of the problems of electric power generation and ion containment. He left no doubt that ion propulsion is feasible and indeed necessary for certain interplanetary missions. Within the next decade, he stated, working units for small vehicles will become commercially available.

As in previous years, Germany's E. Sänger discussed the use of photons, or light beams, for propulsion. These beams would be so enormous that they probably could not be reflected by either solid or liquid mirrors. Sänger therefore suggested the very heavy compression shocks of plasmas (at 150,000 deg K) or the compression shocks of pure electron gas as reflecting mechanisms. Highly theoretical as were his concepts, Sänger yet made an impressive case for the practicality of photon propulsion. For interstellar trips, this method may indeed some day furnish the prime means of moving a vehicle.

Our latest discoveries about the radiation belts around the earth were reviewed by F. Singer, of the University of Maryland. He predicted that penetrating particles caused by neutron decay would pose the only danger to manned space flight, and that only at altitudes of about 600-4000 miles and up to 30 deg magnetic latitude. It would be difficult to devise shielding against this type of radiation, Singer stated, but a space vehicle might get through the dangerous zone fast enough to prevent any damage to its occupants. Singer also pointed out that his theory of using special vehicles to "sweep" out a safe path through radiation had proved valid—the flights of satellites such as Vanguard had proved that "tunnels" could be "bored" in a radiation belt by an orbiting bluff body.—End

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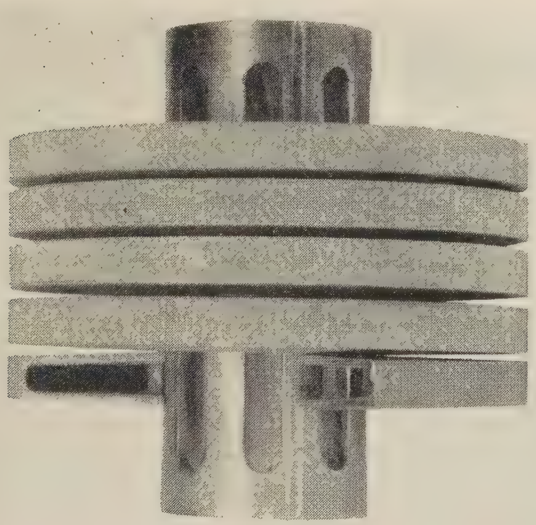
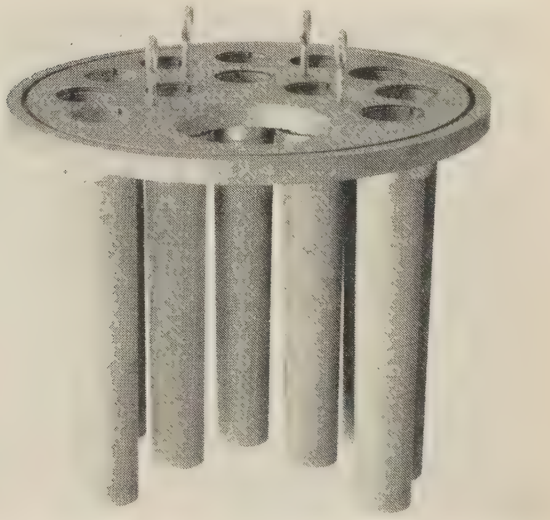




DOUBLE-TAPER, hollow-disk sintered-bronze filter elements (left). Each element is made in one piece and mounted on a ported manifold tube. Right: Sintered-bronze elements with sinter-bonded, threaded adapter attached to the manifold plate. The use of tapered threads eliminates gaskets and provides a metal-to-metal seal.

Choosing filter media for liquid propellants

All fluids have one thing in common: They are subject to contamination. But, that doesn't mean that the filtering of fluids is always the same. On the contrary, filtration is a widely varied field, as is shown for instance in this report on the filter media used in aerospace propellant filters.

by Gerald J. Harman, President, Harman Equipment Co.*

THE media materials for today's propellant filter must withstand extreme temperatures and pressures and have a high filtration efficiency.

Metallic media are suitable for higher temperature and pressure ranges than organic and other non-metallic media. Extremely high temperatures, say, over 700 deg F, usually call for stainless steel.

Practically all metallic filter elements can be produced or reinforced to withstand extremely high pressure differentials, and there is a wide choice of materials. The same is true for temperatures ranging from —320 deg F (or lower) up to about + 700 deg F.

At these temperatures, the nature and characteristics of the fluid to be filtered and the contaminants it contains determine the filter selection. For petroleum-type fluids, which contain waxy particles and flocculent matter as well as solid contaminants, the depth filtration of sintered bronze or stainless is desirable.

Sintered bronze is generally preferable—being available in thicker wall sections, it provides the greatest depth filtration. Sin-

more on next page

* Harman Equipment Co., 3605 E. Olympic Blvd., Los Angeles 23, Calif.

tered stainless should be considered, however, in filtering strong acids at any temperature and in filtering any fluid at extremely high temperatures.

Surface filtration, as provided by stainless steel wire media, is usually all that is needed for liquefied and compressible gases. The contaminants in these fluids are usually free from gummy and other soft substances, so that no depth filtration is needed. However, flocculent matter and stringy contaminants are sometimes found in the systems that handle these fluids.

Some of the stainless wire media will do a good job of removing the contaminants, provided their wall cross-sections have an irregular or zig-zag pore configuration. Micronic filter cloth and Dutch-weave media both have this indirect flow pattern, which traps elongated contaminants with a smaller diameter along their minor axis than the porosity rating of the filter media.

Organic and other non-metallic filter media can be used so long as temperatures are not too high, or too low. Naturally the characteristics of fluid and contaminant must again be taken into account, and the pressure differentials are particularly important.

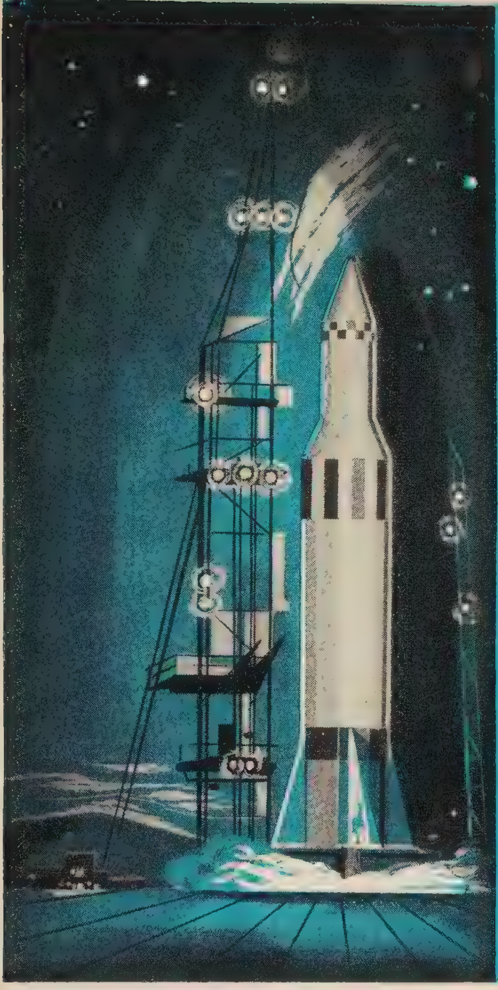
As the differential pressure increases, some non-metallic filter media will expand and create passage channels. As a result, foreign particles larger than the porosity rating of the filter element can sneak through and cause damage.

For this reason, metallic filters are usually recommended whenever the fluid is heavily contaminated. Because metal is rigid, comparatively high differential pressures can be handled without loss in the porosity rating.

As a rule, metallic filter elements cost considerably more than non-metallic and expendable ones. But, in many cases, they cost a lot less to maintain, since they can be cleaned and re-used. This is especially true in filtering highly contaminated fluids, when frequent servicing of the filter element is necessary.

Expendable elements—resin-impregnated paper, fiberglass, and other non-metallic media—can also be used to good advantage in many filtering applications. Fuel-water separation is one of them—

more on page 138



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High strength cases such as the 16″ dia. x 48″ long x .050″ wall thickness have been fabricated and consistently burst at strength levels from 280,000 psi to 325,000 psi dependent upon the draw temperature used. These strength levels are attainable by either the roll and weld or seamless (spun) method of fabricating the tube section.

Hurdle the critical notch sensitivity problem by having Ingersoll fabricate your high strength cases.

The Ingersoll Kalamazoo Division has been producing missile metal parts since 1951 when the first Snark booster cases were made. Today, nearly half the Nike Hercules boosters and sustainers have been made with Ingersoll Kalamazoo Division production skills.

RESEARCH AND DEVELOPMENT and prototype fabrication are going on at the Ingersoll Kalamazoo Division utilizing such new methods as hydrospinning and concussion, or explosive, forming, which provide today's solutions to problems in metal parts production.

FABRICATION AND ASSEMBLY on a PRODUCTION line basis of large missile parts is routine at the Ingersoll Kalamazoo Division involving such processes as annealing, machining, hydrospinning, welding, rolling, etc.

A capable staff of engineers is available at the Ingersoll Kalamazoo Division who are experienced in the DESIGN, FABRICATION AND ASSEMBLY of major missile hardware parts. These engineers are ready to tackle your problems.

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MULTI - PLEATED cylindrical filter element assembly using a micronic stainless-steel wire medium. This design provides about six times as much surface area as a simple cylinder of the same envelope size.

the contaminant load here is small compared with the filter media surface area. When this ratio is favorable, generally only infrequent servicing of the filter element is needed, so that the cost figure is kept reasonably low.

Physical characteristics are important in selecting a filter. For example, generally available sintered bronze elements have about the same corrosion resistance as a good grade of cast bronze of roughly the same composition (about 90 per cent copper and the balance tin). Further corrosion effects can be prevented by electroless nickel-plating or a black-oxide or plastic coating. All these processes can be uniformly applied over the entire cross-section and all other exposed surfaces.

Untreated bronze media are suitable for most fluids with a temperature range of —350 deg F or less to 550 deg F or more. Treated bronze can be used with fluids that are not compatible with plain bronze and at temperatures much higher than 550 deg F.

The uniform size of the spheroidal shaped bronze powder usually used to make the sintered filter provides automatic porosity control and high filtration efficiency. Sintered-bronze filters are available from most manufacturers in porosity ratings ranging from two to 100 microns or coarser.

Sintered-stainless-steel filters are particularly well suited to high heat and corrosion applications. The material is available in preformed shapes, such as small disks and tubes, for incorporation in valves, pumps, nozzles, etc., as well as in sheet form.

New developments in powder metallurgy have made it possible to control such properties as particle size and shape, porosity, pore distribution, and density. In properly made units, media migration of particle discharge is considered impossible by experienced manufacturers, because of the strong metallurgical fusion with each powder particle at several contact points. Normally furnished in 1/16 in. thickness, the sintered-stainless-steel medium is usually stocked in sheets with porosity ratings from three to 40 microns.

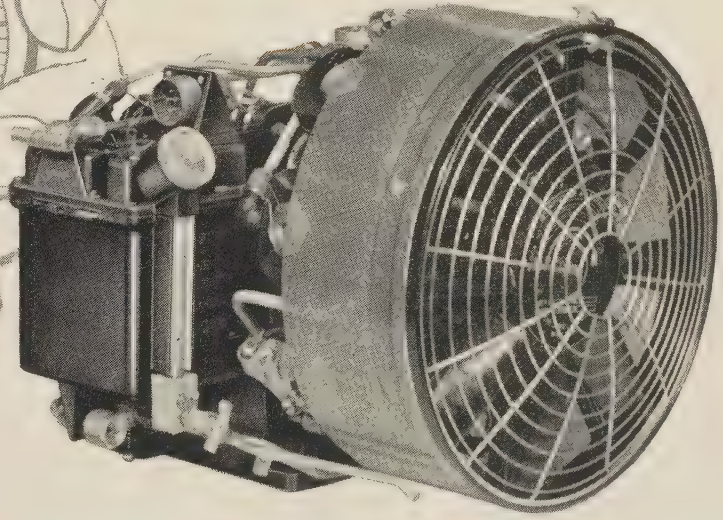
The latest manufacturing techniques for micronic wire filter media use uniform interstice, or pore size, control. As a result, the range between the contaminant particle size retention rating and the largest particle that will pass through the medium is kept to a minimum.

For example, this type of filter medium can retain 90 per cent of all particles larger than nine microns in diameter and 100 per cent of all that are larger than ten microns. For coarser porosity ratings, the range between 90 and 100 per cent particle size retention increases with the pore size of the medium. The broader ranges between these values in the coarser porosity ratings, however, are considerably closer than that of most other filter media, including sintered wire or powder.

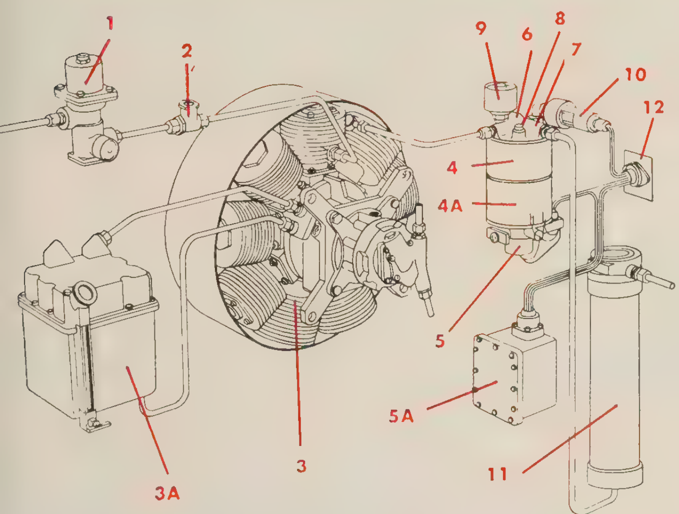
Generally, micronic filter cloth is readily available in 100 per cent particle size retention ratings of 10-70 microns. Dutch-weave filters are usually available in porosity ratings starting at 30 microns and coarser. Both of these filter media are regularly available in stainless steel, copper, nickel, Monel, brass, and phosphor bronze. Write in No. 63 on Reader Service Card for more information.—End

. . . important news about JET STARTING

Cornelius 309 compressor "package." 9 cylinders, 8 to 10 CFM, 3000 psi. This one compact unit includes all of the components named in the schematic drawing (below left).



for reliable "split-second" jet starting equip your jets with Cornelius compressors



1. Absolute Pressure Regulator **2.** Vacuum Breaker **3.** Air Compressor with Hydraulic or Electric Motor **3A.** Oil Reservoir **4.** Moisture Separator **4A.** Thermostatically Controlled Heater Blanket **5.** Condensate Dump Valve **5A.** Condensate Exhaust Timer and Relay **6.** Check Valve **7.** Back Pressure Valve **8.** Switch Rupture Disc **9.** System Relief Valve **10.** Pressure Switch **11.** Chemical Drier **12.** AC-DC Power Input

The Cornelius 309 compressor "package" will soon be operational on five major domestic airlines and five major foreign airlines. It has also been selected for installation on the Allison Prop-Jet Super Convair. This pneumatic system was developed to give jets better, faster starts. It is unmatched for reliability, capacity and longer life. It improves the performance of any jet or prop-jet equipped with a fuel-air starting system.

Here are some facts that demonstrate Cornelius equipment superiority: The 309 compressor is the largest capacity compressor now in production and flying. Its 8 to 10 CFM air delivery is 50 per cent greater than any other available compressor. This larger CFM delivery means greater reliability and longer life because less "ON" time is required for air reservoir recovery; is ideal for short flights.

Specify Cornelius as original equipment. Whether you are an airline or an airframe manufacturer, you are guaranteed to receive a compressor package that is the last word in design and performance — a compressor *second-to-none.*

For *retrofit* programs, replace your small, less reliable compressors with Cornelius 309 compressors. There's a 309 package for every application and it will reduce your maintenance, overhaul and operating costs.

For complete information, qualification test data and installation drawings, contact us today.

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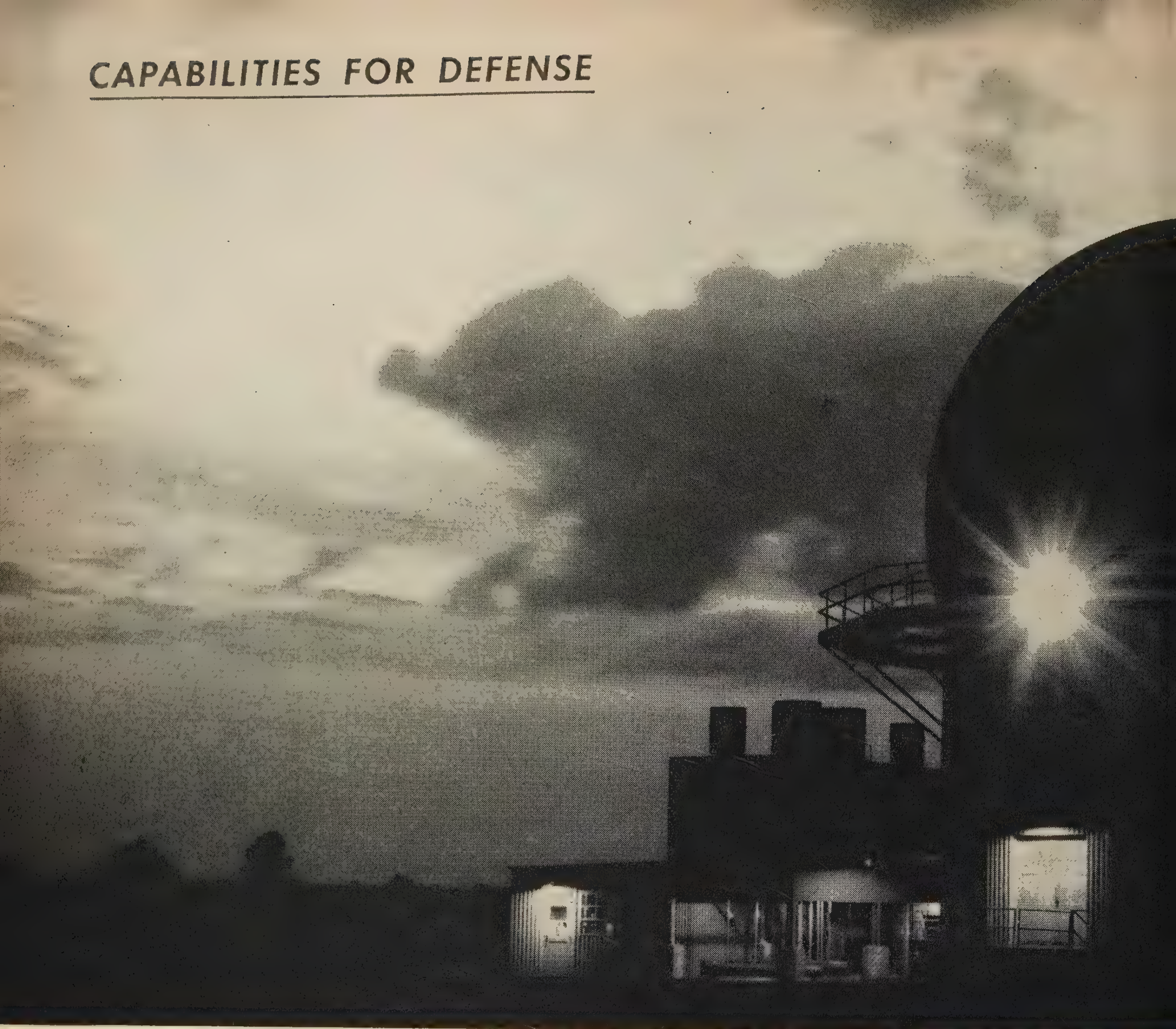
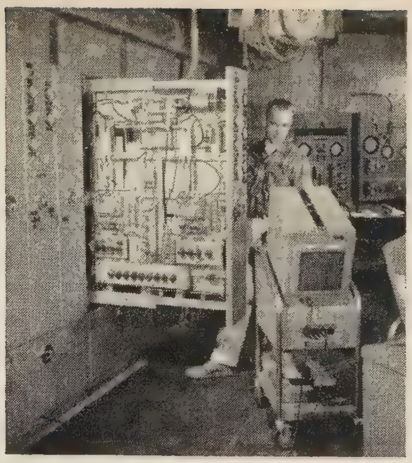
CAPABILITIES FOR DEFENSE



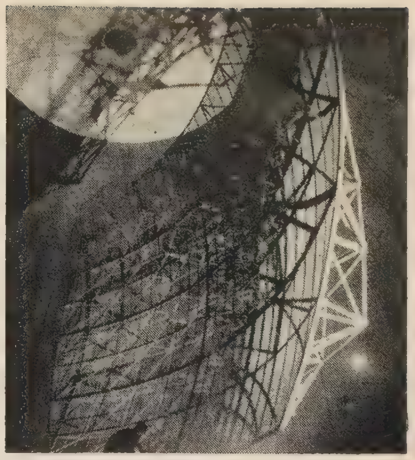
Westinghouse AN/FPS-27 Radar in operation at an Air Defense Command site

A single Westinghouse radar gets a 3-D fi
on the enemy...dilutes his jamming abilit

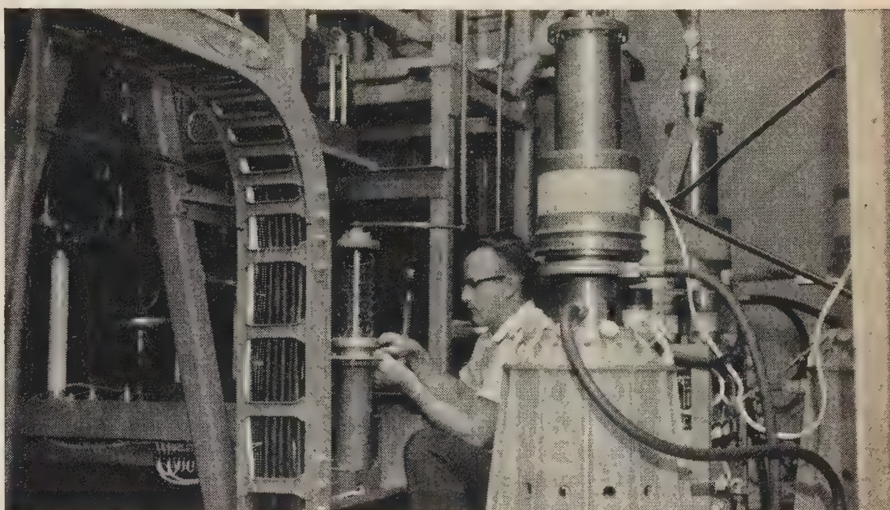
The AN/FPS-27, versatile 3-D radar designed by the Westinghouse Electronics Division for the Air Force's Rome Air Development Center, is achieving new standards of performance, reliability . . . and economy. Now under contract from the Rome Air Materiel Area, this high-power, stacked beam radar gathers range, azimuth and height data quickly and accurately while eliminating unwanted signals. These comprehensive functions in a single radar represent the application of the latest state of the art radar techniques to our nation's early warning defense.



MAINTENANCE EASE: AN/FPS-27 design stresses reliability and maintenance accessibility. A separate monitor console calibrates the receivers remotely. Equipment troubles are automatically indicated. Sub-assemblies can be replaced rapidly in case of circuit malfunction.

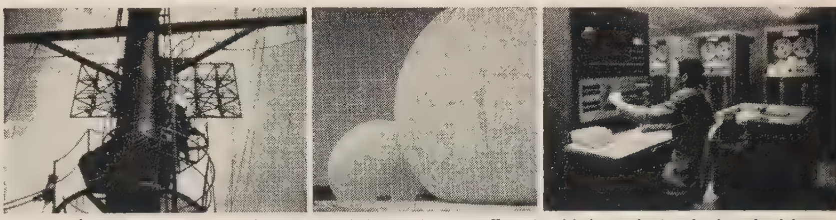


UNIQUE CONSTRUCTION DESIGN of the antenna system permits the inclusion of the latest 3-D height-finding techniques. Range, azimuth and height data can be automatically fed to a computer to form a composite picture of the air defense sector.



EASE OF OPERATION: One man operates the entire transmitter room. This is typical of the operational ease of the Westinghouse designed AN/FPS-27. A minimum team of six specially trained men can handle the operation and maintenance of the entire facility.

is the management team responsible for the develop-
of the AN/FPS-27—within budget and on schedule.
eam is typical of the Westinghouse practice of matching
t to the job.



The AN/FPS-27 is a part of a broad Westinghouse effort in shipboard, tactical and airborne radar. Current simulation studies at the Air Arm Division, utilizing the latest digital computer facilities (at right), hold promise for new approaches to the problem of long-range detection and tracking of aircraft and ICBM's.

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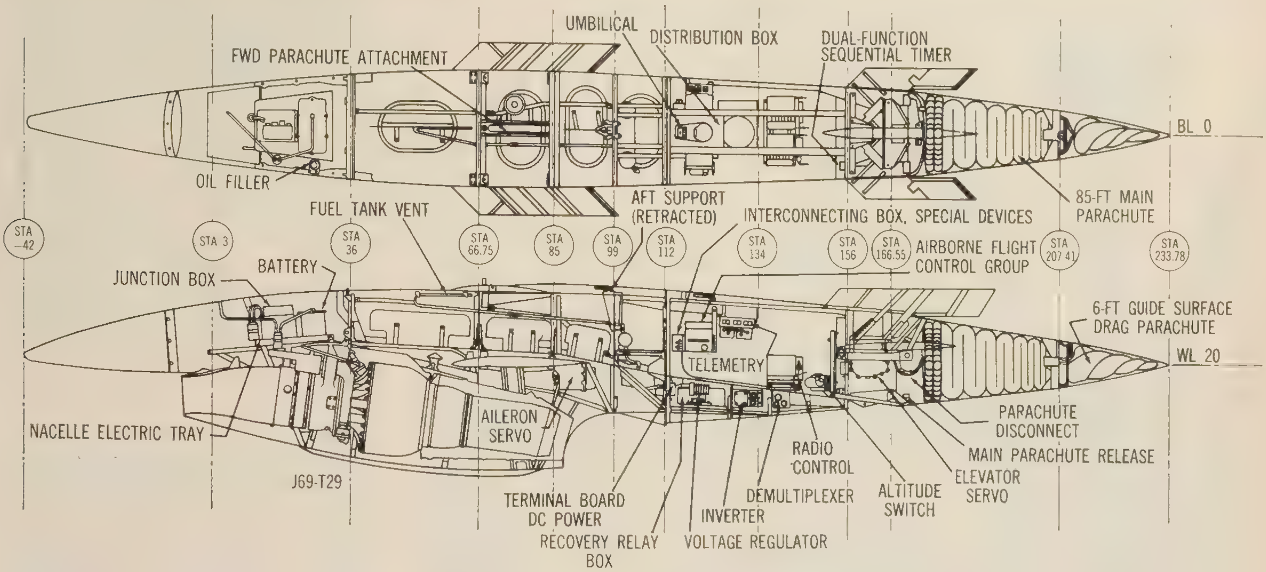

CROSS-SECTIONAL views of Q-2C Firebee target drone.

Firebee design

keeps up with fighter capabilities

As interceptor performance goes up, finding suitable targets for practice becomes quite a proposition. Here is a report on how Ryan is keeping its Firebee drone design, now being produced in a new, improved version, up to the requirements of our latest interceptors and their highly sophisticated electronic equipment.

FOR the second year in a row, Ryan Firebee drones recently were the targets for "Project William Tell", USAF's annual world-wide interceptor weapons meet. During the 1958 meet, observers generally seemed to agree that the use of the Q-2A Firebee provided the most realistic test to date of interceptor weapon systems. This year, the new, improved Q-2C Firebee was used.

The main reasons for developing the Q-2C version, Ryan Aeronautical Co., Lindbergh Field, San Diego 2, Calif. told SPACE/AERONAUTICS, were to get better performance and target augmentation. Flight tests of the new model have already shown that it exceeds the spec requirement of 500 knots for one hour on station at altitudes from 300 to over 50,000 ft. In one case, the -2C achieved 77 minutes on station.

For better augmentation, a larger vehicle than the Q-2A was needed. As more and more different missile systems were used against the -2A, a wider range of augmentation response was required. Because of the small size of the -2A, it was necessary to add pods, reflectors, etc., to make it look bigger. This degraded aerodynamic performance, Ryan notes.

The -2C was designed to have active rather than passive augmen-

more on next page

BETTER performance and target augmentation were the main reasons why Ryan developed the advanced Q-2C from the Q-2A Firebee drone for interceptor practice. The -2C's spec requirement for speed and altitude has already been exceeded in tests.

tation. The earlier model used Luneberg lenses, which, besides being too big, couldn't provide the amount of bistatic reflection response needed with semi-active homing systems. As a result, Ryan developed an active system for the -2C that uses traveling-wave-tube (TWT) amplifiers. These have been designed in L-, S-, C-, and X-band to provide augmentation systems compatible with the Bomarc, Falcon, Genie, Hawk, Hercules, Nike-Ajax and Talos radar complexes, Warren states.

Simpler installations with new TWTs

As greatly improved TWTs have recently became available, much simpler instllations proved feasible. For instance, a single TWT is now used to meet the power and gain needs of two bands—formerly, two cascaded tubes were needed for each band. The new tubes can amplify signals to an average of 30 db above the incoming level with a minimum of delay, retaining frequency, pulse repetition rates, pulse width, and other characteristics, Ryan engineers state. Using the active instead of a passive system also has provided 10,000 ft more radar altitude, it's pointed out.

Omnidirectional coverage is needed in the -2C. In some cases, antenna switching is used. Multiple antennas had to be provided to cover different bands in all directions. As Ryan engineers explain, even for the best condition, where it's possible to cover 180 deg with one antenna for one band, four antennas (two receiving and two sending) are needed. Where one

more on page 147

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37TH AND PERKINS **CLEVITE** CORPORATION CLEVELAND 14, OHIO

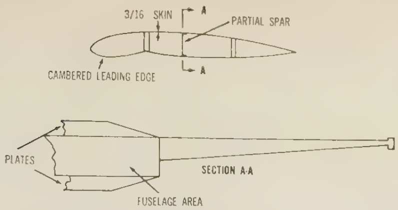

FIGURE 1: Rough sketch of wing area containing internal skin panels (aft of the partial spar) that are chem-milled to save weight. The increased bending moments at the wing center that are caused by the greater area of the Q-2C wing are accounted for by the two plates shown in Section A-A.

antenna can only cover one quadrant, eight antennas are needed for the complete system.

Flush waveguide-type antennas are used. However, there's enough gain in the system to permit coax losses, so waveguides have been eliminated, Ryan engineers explain.

Most of the 300-lb weight increase of the -2C over the -2A is due to the augmentation equipment. However, the -2C is really much more efficient weightwise. One reason for this lies in the impressive improvement in engine thrust. Continental engineers took the J69 engine and developed the J69-T29 version with a thrust of 1700 lb (as against 1050 lb for earlier models). What's more, they did it without a proportionate increase in engine size and weight. The thrust-to-dry-weight ratio of the -T29 is almost 5.

Near-supersonic speeds can be reached

The new engine, it's claimed, lets the -2C to attain near-supersonic speeds. Looking farther ahead, engineering vice president F. W. Fink states that the development of a light-weight afterburner for this powerplant, to be cut in on station, makes a supersonic Firebee possible with an estimated top speed of Mach 1.5.

Fuselage length was increased by 18 in. over the -2A. A ventral fin has been added, and a new vertical fin with only six per cent thickness is used (as against the previous 14 per cent). The wing area of 36 sq ft is a third larger than the -2A's. It was achieved by maintaining the -2A's aspect ratio

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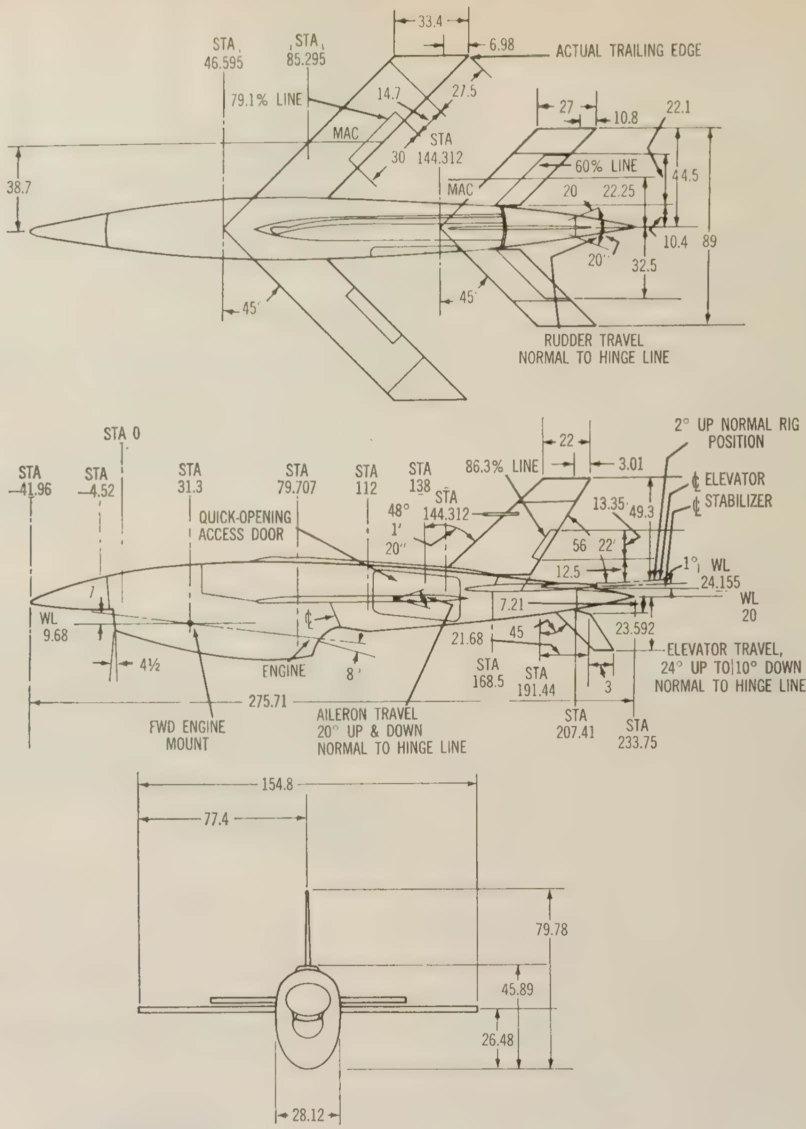

THREE-VIEW of Q-2C. Telemetering, flight control, and similar equipment is slid in and out on trays through the quick-opening access door.

and extending chord and spar in the same proportion. The airfoil section is now cambered instead of symmetrical as it was on the -2A.

Wing skins tapered by chemical milling

To reduce weight, the wing skins aft of the partial spar (*Fig. 1*) have been tapered by chem-milling, providing a saving of eight pounds on eight panels (top and bottom). The skin forward of the spar is 3/16-in. aluminum. The fuel tank floor also is chem-milled.

With the exception of the magnesium wing leading and trailing edges, the structure now consists mainly of 2024 aluminum and of some steel. In the engine exhaust area, 15 lb of weight were saved by replacing steel skins with aluminum structural panels. With this arrangement, an ejector had to be used to suck cooling air into the area between engine and skin. In addition, the engine was designed with built-in shrouding for better heat control. While the skin temperature in this area used to be 250 deg F during engine run-up, it's now ambient and cool enough so you can touch the nacelle with your hand.

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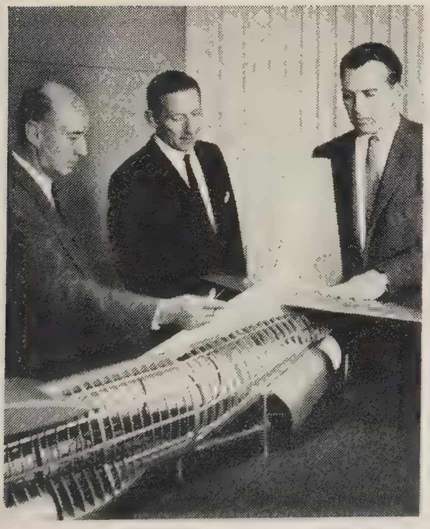
How to put wings on a warehouse

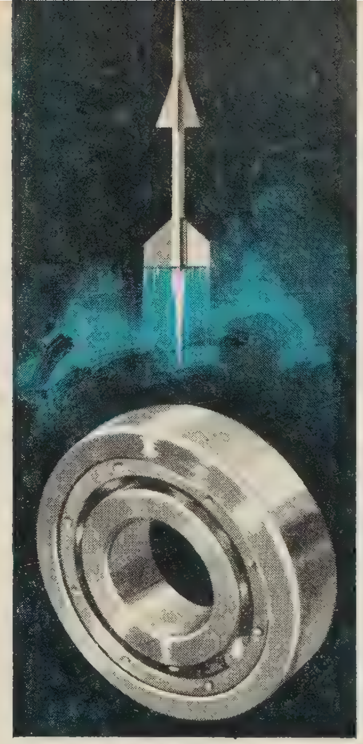


Giving overseas air bases what amounts to local warehouse service on important parts is an Air Force objective. Its present system has slashed delivery schedules up to *20 times*...saved taxpayers several *billion* dollars over the past decade. To improve it further, Douglas has been selected to develop specifications for a comprehensive Material Handling Support System involving better communications, control, cargo handling and loading, packaging and air terminal design. Douglas is well qualified for this program by its more than 20 years in all phases of cargo transport. Air logistics is only one area of extensive Douglas operations in aircraft, missile and space fields in which outstanding openings exist for qualified scientists and engineers. Some are listed on the facing page.

Schuyler Kleinhans and Charles Glasgow, Chief Engineers of the Santa Monica and Long Beach Divisions, go over air transport needs relating to advanced cargo loading techniques with Donald W. Douglas, Jr., President of DOUGLAS

JETLINERS ■ MILITARY AIRCRAFT ■ CARGO TRANSPORTS ■ MISSILE SYSTEMS ■ SPACE SYSTEMS ■ AIRCOMB ■ GROUND-HANDLING EQUIPMENT

c.



d.

b.

a. Lowering a consumable electrode into a vacuum arc furnace. Metals produced by vacuum melting are "cleaner" and therefore offer improved strength, ductility and longer fatigue life.

b. ***Titanium****, more than 1000 lbs. of it, saves 800 lbs. in Convair 880 because of metal's high strength/weight ratio. Principal use is in jet engine pods, aileron, stabilizer, and tail assembly.*

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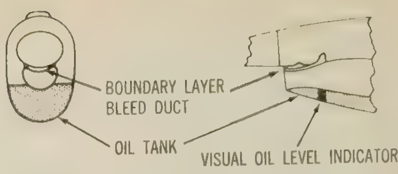


FIGURE 2: Location of bleed air duct and oil tank in the engine intake duct area.

The boundary layer bleed air duct (*Figure 2*) used to cool the shrouding also provides cooling air for the 200-amp dc generator driven by the engine. This duct, it's noted, has also increased the efficiency of the engine intake duct by two per cent.

Oil tank fits around intake duct

As *Figure 2* also shows, the oil tank fits around the intake duct. The latter is made of plastic, so that a visual oil level indicator can be used. The oil system is recirculating. Despite the compactness of its design, there's enough room to get rid of foam in the oil during the return cycle.

The flight control system permits climbing and diving turns by airspeed control. The system is fail-safe, says Ryan, in the sense that, if the operator makes the -2C dive too fast, the control system will automatically cause the drone to start to climb. The reverse is true for too much climb speed. In some cases it's possible to control dive and climb through the throttle. It's even possible to perform a flareout pattern by changing the throttle setting.

The system includes automatic bank angle scheduling; the angle decreases with increasing altitude.

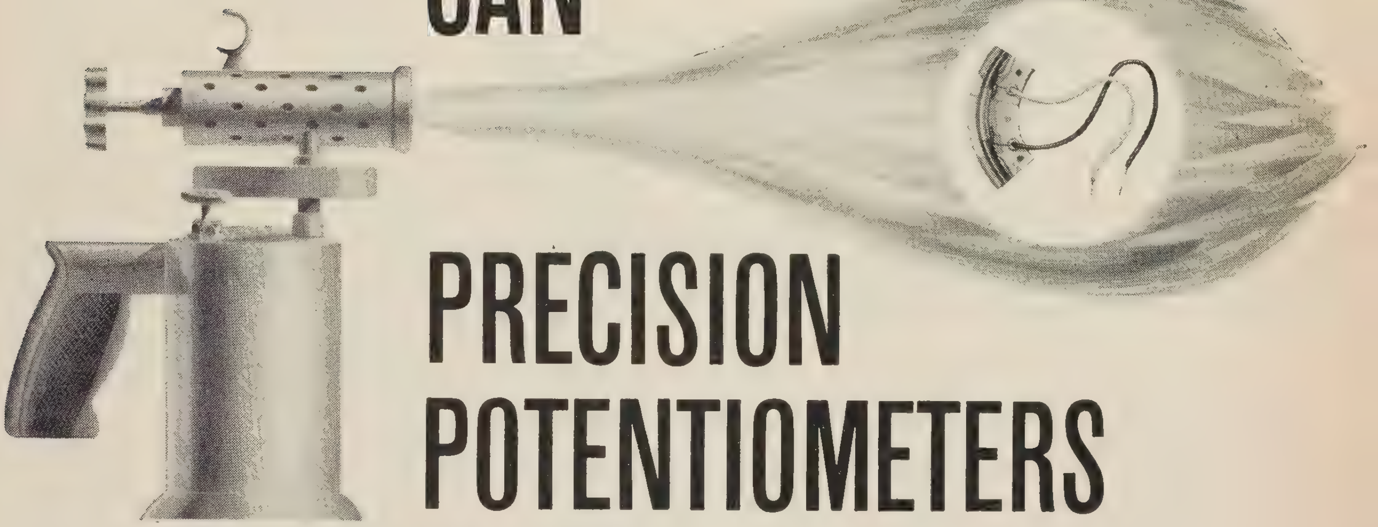
Climbing turn gives Q-2C more flexibility

The climbing turn feature adds a great deal of flexibility. In the past, each turn was locked in the attitude controller and the craft made a straight and level turn. The present system lets the drone get on station as much as six minutes faster than before.

The Q-2C has separate low and high altitude recovery systems. The low altitude system is entirely automatic: Upon receipt of a recovery command or fuel depletion below 15,000 ft, the drone goes into a power-off climb until the airspeed is reduced to 180 knots. Then the

more on page 154

HOW MUCH HEAT CAN



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Special Ketay sector potentiometers have been designed to operate in ambient temperatures up to 500° C.

Ketay precision single-turn, multi-turn, rectilinear and sector potentiometers for control and instrumentation purposes feature compactness and high sensitivity. They are custom engineered for applications once considered too severe because of shock, vibration, torque, resolution or destructive environment.

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Creative Engineering—for example, very accurate single-turn ganged potentiometers in size 9 with linearity as fine as 0.15% and 2″ diameter units with linearity as fine as 0.07%.

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Advanced Manufacturing Techniques—such as the ability to weld taps to a single turn of wire as small as 0.0004″ diameter (1/10 the diameter of a human hair).

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Q-2C Firebee Specifications

Wing

Gross area	36 sq ft
Airfoil section (normal to leading edge)	
Leading edge to 0.264 chord	NACA 009.932
0.264 chord to trailing edge	NACA 63A014.63
Aspect ratio	4.632
Dihedral angle	0 deg
Incidence parallel to plane of symmetry	
Leading edge to 0.264 chord	5 deg 51 min
0.264 chord to trailing edge	0 deg
Aileron area (aft of hinge)	208 sq ft

Horizontal Tail

Gross area	16.69 sq ft
Airfoil section (normal to leading edge)	NACA 63A014.63
Aspect ratio	3.33
Dihedral angle	0 deg
Incidence parallel to plane of symmetry	1 deg
Elevator area (aft of hinge)	3.42

Vertical Tail

Total area (from horizontal tailplane)	11.3 sq ft
Total exposed area of ventral fin	1.43 sq ft
Airfoil section (streamwise)	NACA 65A006
Rudder trim area (aft of hinge)	0.46
Aspect ratio	1.5

Weights & CG

	Weight (lb)	CG (fuselage station)
Gross (basic)	2060	88.5
Empty (basic)	1400	94.1
Most forward	2141	88.7
Most aft	1560	95

Powerplant

(continental J69-T-29)

Rated sea level static trust	1700 lb

The Q-2C has separate low and high altitude recovery systems. The low altitude system is entirely automatic: Upon receipt of a recovery command or fuel depletion below 15,000 ft, the drone goes into a power-off climb until the airspeed is reduced to 180 knots. Then the drag and main chutes are ejected simultaneously, and the drone settles to earth.

In high altitude recovery, the drag chute deploys immediately upon command. The main chute deploys nine seconds later, unless the drone is still above 15,000 ft altitude.

The -2C tracking system can be the AN/DPN-31, AN/APN-91, AN/MSQ-1, or AN/MSQ-1A (radar). The command control receiver is the AN/ARW-59 and the transmitter the AN/ARW-55 or AN/FRW-2.—**IS**

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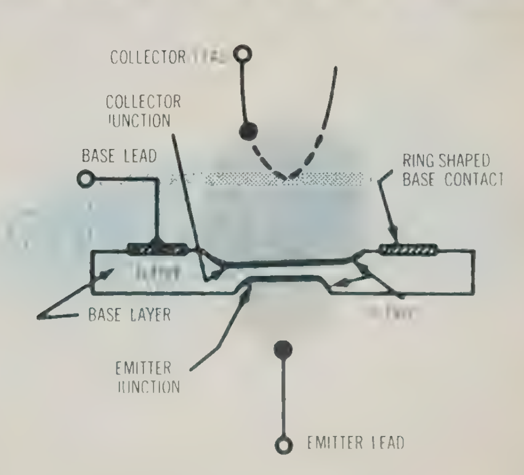

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aerospace electronics intelligence

Lunik shots show accuracy of Red guidance gear

HOW LUNIK II AND III were guided is still a puzzle. Some experts claim the Reds used a radio command system; others plump for a self-contained inertial design. It is believed generally that both vehicles used the same type of guidance.

Whatever system it is, it must be darn good. If we are to believe the Reds—and we have no good reason to disbelieve them in this case—they used only first-stage guidance to send Lunik II crashing into the Sea of Serenity just south of the moon's center (at which they probably were aiming).

The Reds are known to have a fairly accurate inertial system, though it's large and bulky. However, the bulk is not much of a problem to them, since they have super-thrust rockets available. Because of our smaller rockets, our guidance systems have to be miniaturized to the bone, which adds no little to the reliability problem.

SAGE SYSTEM will not be adaptable for use with Nike-Zeus, the anti-ICBM missile, testified William Holaday, special assistant for guided missiles to the Secretary of Defense, before the House Committee on Science and Astronautics. So far the government has spent $2 billion on Sage; it will spend some $7.5 billion before the the system is completed, Holaday told the committee.

Mace uses Pinpoint, developed from Atran system

PINPOINT, a self-contained, long range, automatic guidance system for missiles and aircraft, has grown out of Goodyear Aircraft's Atran system. A radar map matcher, Atran is used on the Martin Mace missile.

According to Goodyear, Pinpoint combines Atran's best features with dead reckoning and inertial guidance equipment. It overcomes the inherent inability of a map matcher to work over long stretches of water and barren terrain where there are little or no significant surface features for comparison of the radar image with a stored map.

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FOUR HEAVILY electronified satellite projects are being shifted from ARPA to the military services as result of DOD's realignment of space program responsibilities. The complete shift will take about a year. Projects Samos and Midas went to USAF, Project Transit went to the Navy, and Project Notus went to the Army.

Samos is a recon satellite on which Lockheed is the prime contractor.

Midas is a satellite for early warning against ballistic missiles, also with Lockheed as the prime.

Transit is a navigation satellite on which the Johns Hopkins Applied Physics Lab is the prime contractor. It will send out coded signals giving its track over the globe. Ships and aircraft receiving these can fix their position by measuring the amount by which the signals have shifted in frequency because of the Doppler effect.

Notus is a group of satellite communications projects. In its first phase, known as Project Courier, a group of delayed repeater satellites will be launched to supply global communications.

Courier is already well underway. Its ground station electronics is being built by ITT Labs, its ground antennas and instrumentation by Radiation, Inc., and its satellite-borne repeaters by Philco.

Notus also will include a polar communications satellite, on which GE's Missile & Space Div. and Bendix' System Div. are working. GE will handle the satellite end and Bendix the communications subsystem.

LF homing beacons used in new Boeing landing system

RADICALLY SIMPLE instrument landing system is being developed by Boeing. Two low frequency homing beacons are installed at the approach end of the landing runway—one along the runway centerline and the other at a known distance to the right or left of the centerline.

The landing aircraft would need two ADF re-

more on next page

Cover story — Photomicrograph of a cross-section through an alloy-junction PNP transistor made at Western Electric. Basic wafer is 0.08-in.-square, 0.003-in.-thick germanium. Impurity metals are alloyed into its faces. As a switch, the alloy transistor performs outstandingly in the low and medium speed ranges.

ceivers, a special filter, and a coupler to derive its lateral and longitudinal position relative to the runway. Height would be gotten from a radar altimeter. The filter and coupler would weigh less than 10 lb, says Boeing.

BOTH POSITION and altitude data would be displayed to the pilot to guide him into the landing. So far as one can tell from the scant information released by Boeing, flareout evidently would be a manual maneuver flown by the pilot.

Boeing claims the system has more than 40 hours of flight test time, including 60 successful approaches. (No mention was made of an actual landing with the equipment, even though Boeing does speak of a "landing system.")

Communications test planned with 20 satellites

SATELLITE BOUNCE communications test link is being set up over a 2300-mile transcontinental span between NASA's Goldstone, Calif., tracking station and a Bell Labs station under construction at Holmdel, N.J. Plans call for launching some 20 satellite spheres that will orbit the earth at 1000 miles altitude. Signals will be ricocheted from one station to the other to check such parameters as signal quality, bandwidth potential optimum frequencies, communications horizons, etc.

The first satellites, to be launched by NASA, will most likely be aluminized plastic balloons of 100 ft diameter. They will be inflated in space.

HORN-REFLECTOR antenna and maser or parametric pre-amp will be used by Bell to receive the signals from the satellite reflectors. The horn—about 50 ft long and with an aperture of 20x20 ft—will be mounted on a rotatable platform at the Holmdel site. Transmission from Holmdel will be via a conventional parabolic dish, says Bell.

Depending on experimental results, Bell will use either a pair of parametric amplifiers, a pair of masers, or a combination of the two in the receiver front end. The frequency of the link will be in the one-kilomegacycle range. The power output from the Holmdel site will be around 10 kw.

TRACKING the satellites will be one of the biggest problems of the experiment. It is believed that no satellite-borne beacons are planned—the spheres will have to be "skin-tracked" by radar.

The satellite experiments probably will be preceded by test transmission of signals with the moon as the reflector, says Bell.

The test link will be an important part of project Echo, soon to be announced by NASA. In this project, NASA will launch many passive reflector satellites and will encourage military and commercial electronic communications developers and experimenters to use the earth-orbiting reflectors to get their own experimental data.

•

3-D RADAR is the outstanding feature of the extensively electronified British carrier H. M. S. Victorious, which was shown off to our Navy last July at Norfolk, Va. This Type 984 radar is one of the most advanced in the Royal Navy and is highly classified. It uses a rotating microwave lens antenna. Range and azimuth are gotten conventionally; height is gotten by a stacked-beam system that covers some 50 deg in the elevation plane.

Computations in the radar system are analog. The radar as well as its display are compatible with the Mk 10 IFF system.

DATA REDUCTION will be one of most critical problems in satellite recon systems. Look for a substantial effort in the design of small, prepackaged film storage units that can be carried by the satellite and are automatically developed in orbit. The developed film would then be scanned in facsimile fashion and transmitted back to earth.

The advantage of fax technique is that it does not require telemetry bandwidths for TV. However, it does require a more complex ground receiving station for building up the picture from sequential strips transmitted from the satellite.

Twenty-pound IR detection system claimed possible with new cooler design

EIGHT-OUNCE "MinIRcooler" refrigerator invented by two A. D. Little Co. engineers, can cool IR cells down to —350 deg F. It makes it possible to recycle helium without using large cryostats. A complete airborne detection system based on the new cooler would weigh 20 lb, claims Little.

A bootstrap process is used. Low temperature compressed helium gas is passed through a small engine to a ¼-in.-diameter, two-inch-long tube at the end of which is the IR cell. The gas

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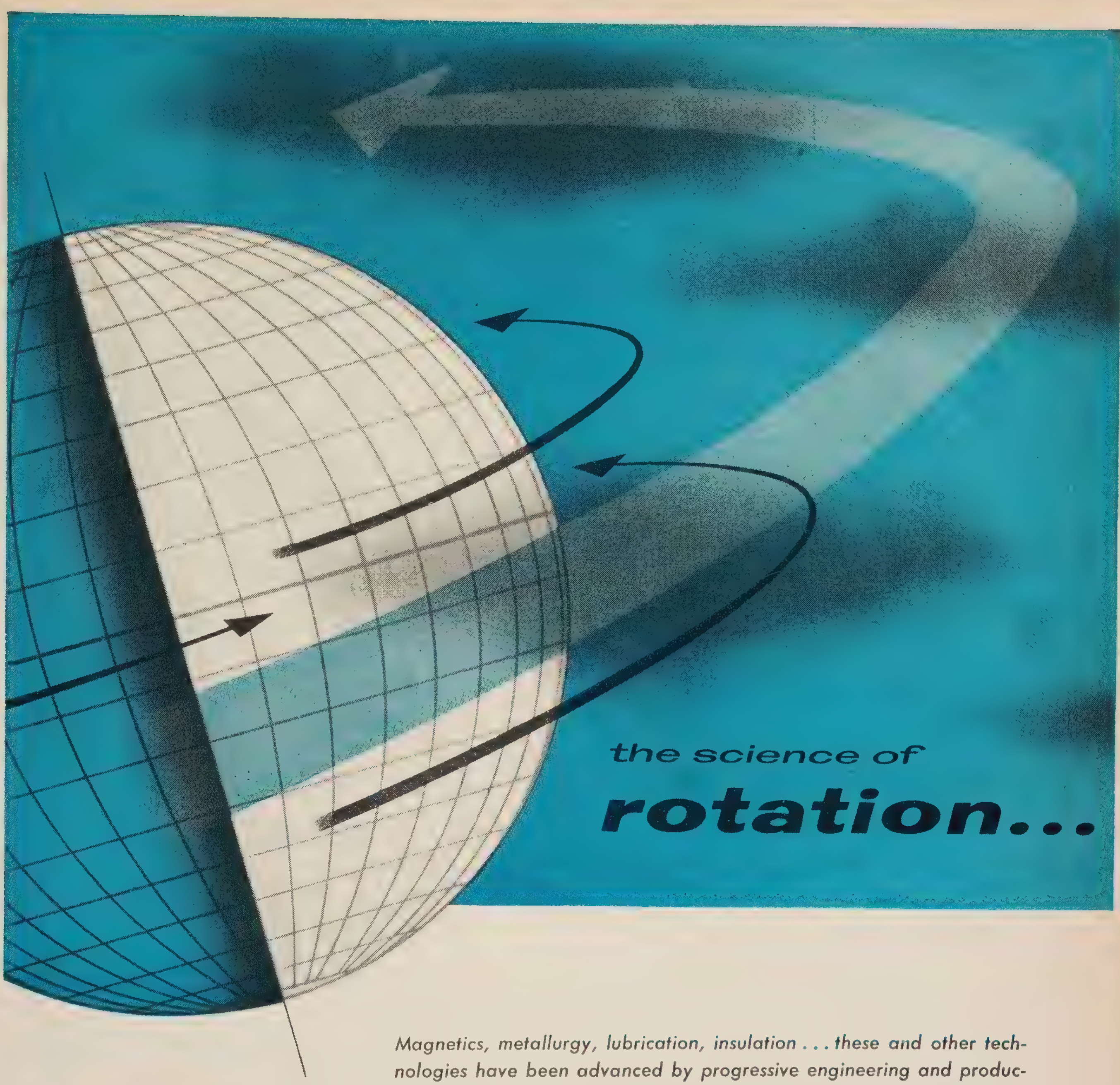

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expands in the tube, cools off the cell, and then is used to cool the compressed helium entering the engine.

The MinIRcooler takes three minutes to reach —315 deg F.

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ARMY REVEALED the Lacrosse can be used for both close and general support, thanks to the mobility of its ground guidance station as the reason. The guidance system of the Martin-Orlando missile includes an angular tracker, a computer, a range and direction indicator, and a power supply. It also has a target-locating device that precisely measures range and elevation.

Initial firing direction and trajectory for Lacrosse are figured out by conventional gun-laying and artillery fire-direction methods. After launch, the missile is acquired by the tracker, and the ground computer guides the missile until it dives and hits the target.

NEW Inertial Guidance Lab is planned by ARDC. It is to be located at AF's Missile Development Center (AFMDC) near Alamogordo, N. M., is expected to be fully operational by '63, and will be staffed by 350 engineers and technicians. The present facilities at AFMDC include a 35,000-ft high speed captive test sled track and a stratosphere chamber. These will be used to support the inertial guidance work.

ATHENA solid-state computer, built by Remington Rand for Titan's ground-based guidance system, completed its initial acceptance test run of 48 hours without error or failure and performed reliably in many other trials, Rem Rand told SPACE/AERONAUTICS. At one stage, the largely handcrafted Athena operated for over 11,000 hours with an average performance record of 99.89 per cent reliability.

Giant radar antenna to help determine problems of ICBM detection

THE LARGEST known radar antenna will be built in Puerto Rico for ARPA. It will be made of aluminum mesh shaped in the form of a saucer, have a 1000-ft in diameter, and be fixed to look directly upwards.

The Puerto Rican facility will include a high powered radar transmitter and a sensitive receiver, both operating on 400 mc, and supporting instrumentation and computing equipment. It will cost some $4.5 million, according to DOD announcements. The performance of the system will be good enough to pick up a one-cubic yard target at 20,000 miles, claims DOD.

PURPOSE of the facility is to provide scientific measurements on the upper atmosphere and the radiation belts surrounding the earth and observations of the moon, the sun, Mars and Venus. Many of the resulting data could help us decide answers to whether it is feasible to detect ICBMs from their interactions with atmospheric layers.

Cornell U. will design and build the facility. Completion in two years is expected.

Amplitrons and TWTs are used in Raytheon antenna

BOX-CAR radar antenna made by Raytheon is 104 ft long and weighs some 50 tons. Installed at Houma AFB, La., it is part of Raytheon's AN/APS-28 heavy-weight air surveillance radar, developed under a $20 million USAF contract. The FPS-28 uses amplitrons and traveling wave tubes in its microwave section. Final system tests are to start soon at Houma.

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MISSION and traffic control package for supersonic NAA's B-70 Valkyrie bomber will be designed and built by Motorola's Military Electronics Div. It will include communications, navigation, and identification (IFF) elements. Motorola heads a team of nine subcontractors on the project.

DANISH AIR FORCE is buying $330,000 worth of airborne radar from Du Mont. The order is for the APS-42B, a surveillance, weather detection, and obstacle avoidance set that Du Mont produced a few years ago for the U. S. Navy. This radar design is obsolete by today's standards.

The APS-42B works in X-band with 50-75 kw peak power.

INFRARED proximity fuze system is used on the de Havilland Firestreak. Two rows of triangular windows girdle the body of the British surface-to-air homing missile and admit radiation to the detectors. The bird's guidance system consists of an optical telescope mounted in a faceted, optical-glass nose cone. From there, information is fed to a proportional navigation computer that sends course corrections to the control system.

electra/JET courtesy of Western Airlines

Another Consolidated Systems achievement. Today, a national effort is being made to collect flight load data in military and commercial aircraft. The goal is statistical prediction of structural failure and engine malfunction—Air Safety. By editing large amounts of analog data at high rates of speed and conditioning it for entry into a digital computer, Consolidated converts the measurement of physical quantities to significant figures... bridging the gap between raw data and air safety. For full information write for Bulletin CEC 3021-X5.

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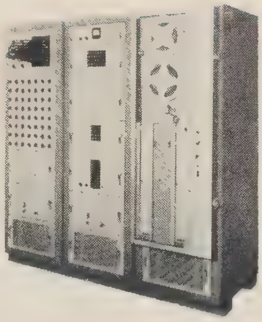

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production & materials engineering

11

What makes a good

thermoelectric material?

- Electric and thermal conductivities, thermoelectric power are basic parameters
- Simplified figure of merit has been worked out by Soviet researchers
- Materials research underway for large and small junction differentials

by Gordon Steele, Technical Staff, Research Div., Servomechanisms, Inc.*

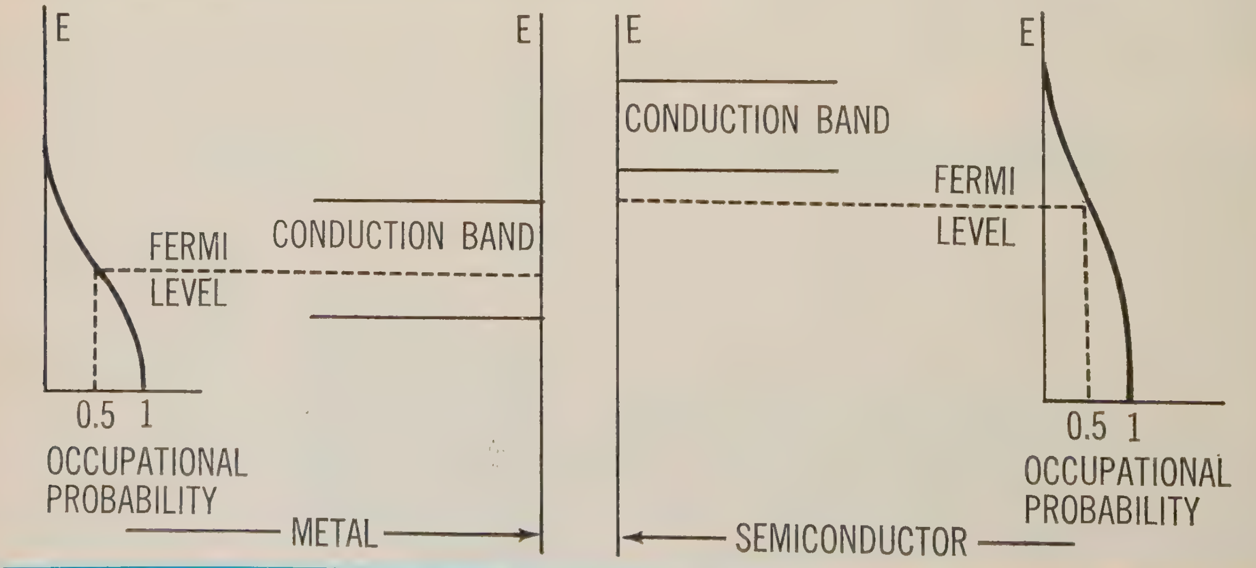
THERE ARE TWO basic thermoelectric effects in materials—the Thomson effect and the Peltier effect. The summation of these two is sometimes called the Seebeck effect.

An emf due to the Thomson effect is generated in a single body of material—say, a bar of metal—when one end is raised to a higher temperature than the other. Although the Thomson emf exists in all thermoelectric circuits, it actually plays a minor role in thermoelectric research.

In the Peltier effect, an emf occurs at the junction of two dissimilar materials. For example, consider a metal and an N-type semi-conductor whose energy band levels

* Research Div., Servomechanisms, Inc., Goleta, Calif.

FIGURE 1: Electric energy distribution at the thermojunction.



and electron distributions are related in a typical case as shown in *Figure 1.* Brought into contact at one end, the two materials tend to a state of equilibrium in which the electron distribution curve is the same on both sides of the interface.

In *Figure 1,* electrons will flow from the semiconductor, in which they are distributed over relatively high energy states, into the metal. The initial difference in the Fermi levels of the two materials is a measure of the driving emf of the electron flow.

If now the two materials are brought into contact at the other ends, a closed circuit is formed (*Fig. 2*). When both junctions are at the same temperature (T_1) the two junction emfs oppose and nullify each other.

A temperature change effects electron distribution more strongly in a semiconductor than in a metal. Therefore, if the temperature of one junction is *raised* to T_2, the electron driving forces at the two junctions will no longer be equal and there will be a net junction emf, or Peltier emf.

It can be shown that keeping temperatures at the junctions constant implies the absorption of thermal energy at the hot junction by the electron flow, which transports the energy to the cold junction. There part of the energy is "evolved"; the remainder is available for electrical work. The highest thermoelectric emfs will occur in couples whose arms are an N-type and a P-type. The thermocouple used for temperature measurement is a well-known example of this effect.

Electric energy turned into heat

Conversely, if an externally driven electric current is sent through a junction, heat will be absorbed or produced, depending on the flow direction. The conversion of electric energy into heat is called the Peltier effect.

If a source of emf, such as a battery, is inserted into a thermoelectric circuit that is at a uniform temperature, one of the circuit's junctions will rise in temperature and the other will fall. A thermoelectric emf developed by the temperature difference will, of course, appear as a counter emf. The direction of transformation between thermal and electric energy will now be reversed; heat will be absorbed at the cooled junction and generated at the heated junction. Thus the system acts as a heat pump.

The basic factors controlling the efficiencies of such a thermoelectric device as an electric power generator are rather obvious. First of all, the electric conductivity of the materials used must be as high as possible to avoid I^2R loss, which would destroy the efficiency. Obviously, too, the thermal conductivity of the materials should be as low as possible, so that as little of thermal energy as possible will be conducted through the materials from the hot junction directly as heat and wasted at the cold junction.

The higher the voltage generated at the junction, the

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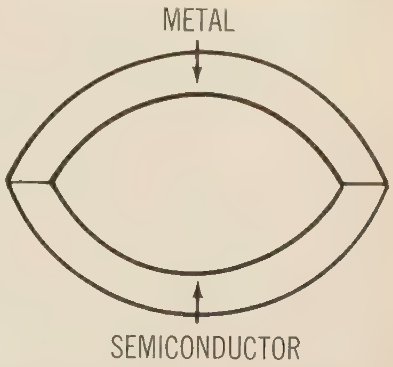

FIGURE 2: Simple thermoelectric configuration. The semiconductor is an N-type.

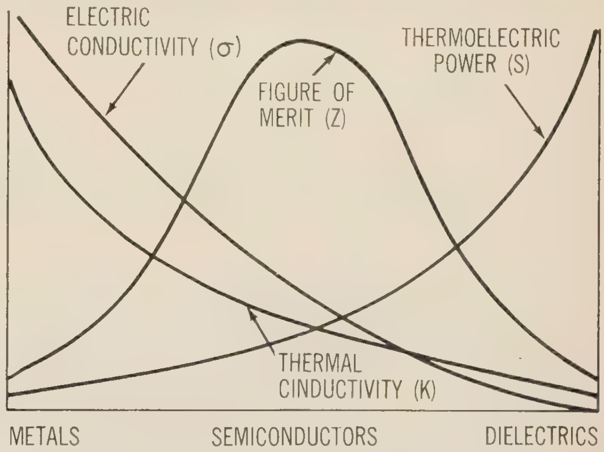

FIGURE 3: Relation of thermoelectric parameters to type of material.

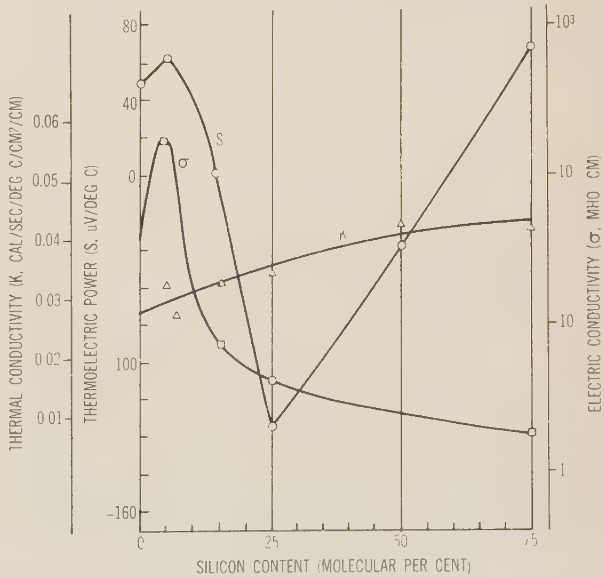

FIGURE 4: Thermoelectric properties of $TiO_{1.8}$ doped with silicon.

Thermoelectric Properties of the Titanium-Oxygen System

Silicon Content (molecular per cent)	S (V/deg C)	K (cal/sec/deg C/cm²/cm)	σ (mho-cm)	Figure of Merit (Z)
$TiO_{0.3}$	4.79.	0.034	1820	2.9×10^{-7}
TiO	5.44	0.029	622	1.5×10^{-7}
$TiO_{1.66}$	36.7	0.026	128	1.6×10^{-6}
$TiO_{1.96}$	189	0.025	14.5	5.0×10^{-6}
$TiO_{1.995}$	410	0.024	2.33	3.2×10^{-6}
$TiO_{1.999}$	507	0.029	1.10	$2\ 3 \times 10^{-6}$

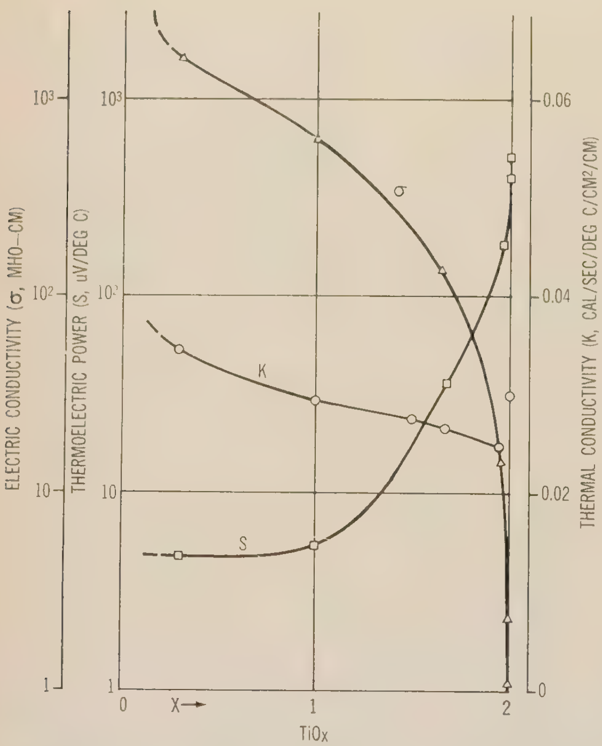

FIGURE 5: Thermoelectric properties of the titanium-oxygen system.

higher will be the efficiency, since more power can be generated with less current and thus there is less I^2R loss. The study of thermoelectric materials therefore centers around the study of electric conductivity (σ), thermal conductivity (K), and thermoelectric power (S), which are also the basic parameters in the design of any thermoelectric power generator.

Electric conductivity, simply is a function of the number of carriers and their mobility.

Thermal conductivity in a solid is more complex. It depends on two basic mechanisms. One involves the conduction band electrons. As these flow through a material, they can transport heat energy and so represent one component of heat conduction. This component depends on the concentration of electrons and their mobility.

"Phonons" analogous to photons

The second mechanism of heat conduction in a solid is known as "phonon conduction." It can be explained by analogy to electronic radiation theory. For many purposes, electronic radiation can be treated as a cloud of energy corpuscles—the so-called "photons", or "quanta". The photon of energy is proportional to the frequency of the associated radiation. For example, the radiation pressure against a solid can be derived, as was done by Einstein, by using the equation of gas-kinetic theory as applied to corpuscles.

Elastic waves in a solid can be similarly treated. Sound waves, of course, are elastic waves, and so are thermal vibrations. Since a crystal structure consists of coupled atoms, the thermal vibrations of one atom cause this atom's neighbors to vibrate. The vibrating atoms produce thermoelastic waves, which travel back and forth in the solid in all directions. Like electromagnetic waves, these waves can be represented as a cloud of energy corpuscles, which in this case are called "phonons".

Instead of thinking in terms of lattice vibrations of larger amplitude and higher frequency which are present at the hot end of a bar as compared with the cold end, in the study of thermal conduction it is more convenient to think in terms of phonons, which are present at the hot end in greater abundance and with a higher energy. There is a net diffusion of phonons from regions of higher temperature to regions of lower temperature. Each phonon represents a definite amount of energy and the phonon diffusion flow a heat current.

In metals, the conduction band contains a high electron density, and the major share of thermal conductivity is due to the transport of thermal energy by electron flow. In insulators, the electron density is extremely low, and thermal conductivity is due almost exclusively to phonons. In semiconductors, the electron density lies between that of metals and insulators, and both electrons and phonons contribute significantly to thermal conduction.

The *thermoelectric power* for a given material is the electric voltage generated in conjunction with a reference material, usually a metal, connected as in *Figure 2* and with the two junctions at different temperatures. The emf is expressed in microvolts per degree C of temperature difference between the junction and is an inverse function of the concentration of carriers in the material.

All thermoelectric generators are composed of two elements operating as the two legs of the junction. The parameters governing the merit of a particular junction

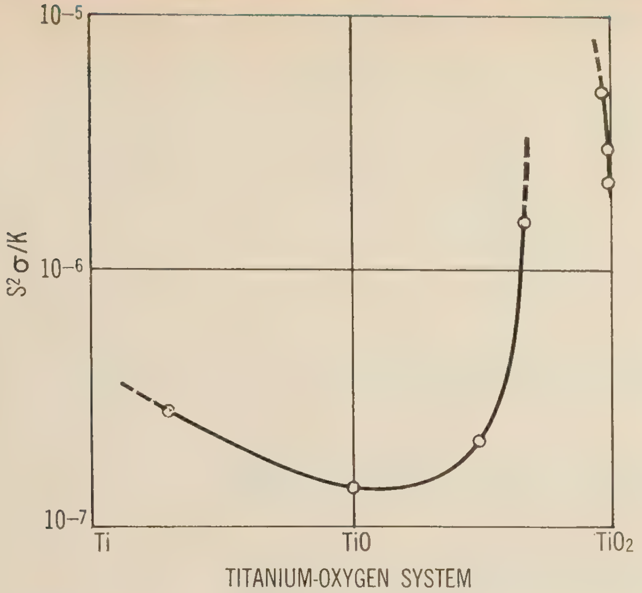

FIGURE 6: Thermoelectric merit of the Ti-O system.

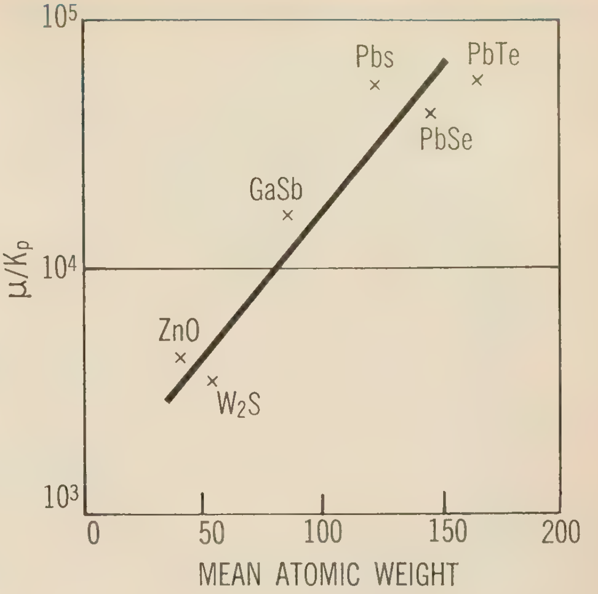

FIGURE 7: Figure of merit vs mean atomic weight.

are related to those of the elements by:

$$F_{a-b} = (S_a - S_b) / (\sqrt{K_a/\sigma_b} + \sqrt{K_a/\sigma_b}),$$

where F is the "figure of merit" and subscripts a and b refer to the metal and the semiconductor, respectively. In any study of thermoelectric generators, we must try to find the factors that determine F and its maximization. For practical reasons, each material in such a study is usually examined with respect to one other material—copper, for instance.

A simplification of F has been used in all the Russian work for examining single elements in this fashion and is described by Ioffe;[1] it is now used throughout the field. This simplified quantity is defined as:

$$Z = S^2\sigma/K.$$

For maximum Z, S and σ should be maximized and K minimized. Now maximizing S calls for minimizing the number of carriers, while maximizing σ calls for maximizing the number of carriers. Minimizing K calls for minimizing the number of carriers, their mobility, and the phonon contribution.

These are obviously conflicting requirements. If the number of carriers is reduced to increase S, σ will decrease, creating a negative effect. At the same time, K will also decrease, creating a positive effect.

If the mobility of the carriers is increased, S is improved slightly and σ is improved a great deal—but K is also increased, producing a negative effect. Obviously the design of optimum material calls for full knowledge and extremely careful control of the carriers and their mobilities. This in turn implies extremely careful control of the purity of the materials.

One factor outside the interlocking relationship of σ, K, and S is the phonon conduction contribution to K, which is a function of the crystal lattice constants of the materials. Therefore all steps should be taken to minimize phonon conduction.

A proper mixture of dissimilar ions in the crystal lattice reduces phonon conduction by increasing the "phonon scattering" and so reduces effective phonon mobility. In Russia, Ioffe used a mixture of bismuth telluride and bismuth selenide to cause discontinuities in the crystal lattice for increased phonon scattering.

If you study the factors in the equation for Z, you can see what general type of materials should be considered for a thermoelectric generator. *Figure 3* plots these factors as well as Z over the range of materials from metallic conductors through semiconductors to dielectrics.[2] Z reaches a maximum in the general area of semiconductors. For metals, σ is favorably high, but S is very low and K is unfavorably high. For dielectrics, S becomes very high and K is favorably low, but σ is impossibly low. Thermodynamic efficiency must also be considered in the design of a thermoelectric power generator. With given materials, the efficiency of the overall device is proportional to the difference of the absolute temperatures of the hot and cold junctions. A generator operating with a 1000-deg C difference between the junctions would be much more efficient than one operating with 300-deg C difference. This consideration has led to two materials programs at Servomechanisms Research Lab.

Goal is the highest possible Z

The first program concerns materials for thermoelectric power devices for operating at low temperatures (below 300 deg C) with a small temperature difference between the hot and cold junctions. Its goal is to find materials with the highest possible Z. According to our present data, these materials will most likely be intermetallic semiconductors—such as lead telluride and bismuth telluride—that, because of their physical properties have high Z values but are limited to lower

(1) A. F. Ioffe et al, "Termoelektricheskoe Okhlazhdenie" (Thermoelectric Cooling); '56.

(2) DeVries & Roy, "Phase Diagrams for Ceramists" (p. 64); Am. Ceramic Soc. '56.

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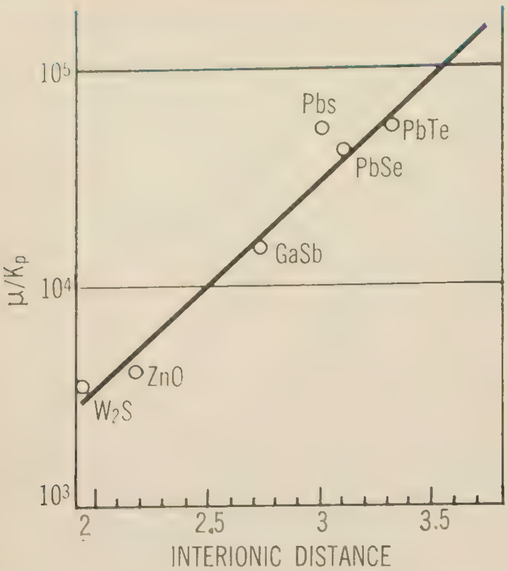


FIGURE 8: Figure of merit vs interionic distance.

temperature ranges. Doping will be used to form N- and P-materials.

The second program involves materials for operation at a hot-junction temperature of at least 1100 deg C. These temperatures obviously call for refractory materials, and temperature stability must take precedence over straight maximization of Z. So far it appears that the Z values of these materials will be lower than those attained by intermetallic semiconductors, the high temperature differential may make up the difference. The materials of interest are the non-stoichiometric refractory compounds, such as the titanium suboxides. Also of interest are impurity-doped refractory materials.

When we started the second program, the high thermoelectric power values (on the order of 2, -10,000 uv/deg C) reported in the literature for materials like lead oxide and bismuth oxide looked very interesting. A quick check of the doping possibilities for these materials resulted in uncertain data, probably because of inadequate control of carrier concentration and purity. A series of lead oxide specimens were produced by P and N doping with potassium oxide and bismuth oxide. The conductivities of the resulting materials generally remained unsatisfactorily low, and it was difficult to measure the thermoelectric power because of high resistivity.

Interestingly enough, however, one sample of PbO doped with Bi_2O_3 showed an unusually high thermoelectric power on the order of 60,000 uv/deg C—higher than any value we measured in the lab or could find in the literature. The sample's output against copper was about six volts, operating on a 100-deg C thermal gradient. Its resistivity, however, was 10^{11} ohm-cm, which makes it unsuitable for any practical use.

Another preliminary series of tests was run on a group of $TiO_{1.8}$ titanium oxide samples doped with zero to 75 molecular per cent of silicon. We chose the $TiO_{1.8}$ mostly as a "stab in the dark" to gain experience with the measurement problems in one range of materials and to get a feel for the effects of the doping of suboxides.

The results of this series of tests are rather interesting: although the K remains reasonably constant, σ and S vary widely (*Fig. 4*). Attempts to measure the Hall effect for doped $TiO_{1.8}$ showed that the effect was too small to be measured accurately with the equipment we had. It is slightly less than one per cent of the Hall effect measured for bismuth.

The curve for S shows a maximum at five molecular per cent of silicon. Since the thermoelectric voltage is positive in this region, by convention the material would be an N-type semiconductor. A second maximum in the curve for S occurs at 25 molecular per cent of silicon in the region of negative thermoelectric power which, by convention, would define the material as a P-type.

The value of σ, after an initial increase at five molecular per cent of silicon, decreases through the rest of the series, as would be expected in view of the increased silicon content. Not enough data were taken to give the exact location of the maxima.

The thermoelectric properties of the titanium-oxygen system without the addition of doping materials was also explored—over the range from TiO_3 to TiO_2 (*Fig. 5 & Table*). The resulting curves showed the normal tendencies of the three parameters that would be expected for the transition from metal through semiconductor to insulator. However, when Z is calculated from these data, it shows an abrupt maximum in the region of $TiO_{1.85}$ (*Fig. 6*).

The search for additional controlling parameters for the thermoelectric efficiency of materials led us to examine some of the work done by Goldsmid.[3] In one attempt at correlation, he plots the efficiency factor of various known materials on which data are available against the materials' mean atomic weights (*Fig. 7*). The efficiency factor used in this case is μ/K_p, the mobility of the carriers divided by the phonon contribution to thermal conductivity.

In using this ratio as a figure of merit it is probably assumed that the interlocking effects of the number of carriers effectively remove the carriers as a variable in the type of materials under discussion. This leaves carrier mobility and phonon conduction as the two controlling variables. The curve in *Figure 7* shows a possible straight-line relationship between the figure of merit and mean atomic weight.

Less scatter for interionic distance

As some of the basic ideas suggested by Ioffe were extended further, researchers at our Lab came to believe that interionic distance would much more nearly be the controlling factor rather than mean atomic weight. We replotted the data of *Figure 7* against interionic distance (*Figure 8*), getting an almost linear relationship to *log* μ/K_p but with fewer scatter points than in Goldsmid's plot. Since the figure-of-merit scale is logarithmic, it can be reasoned that even modest increases in interionic distance would provide significant improvements in the thermoelectric material.

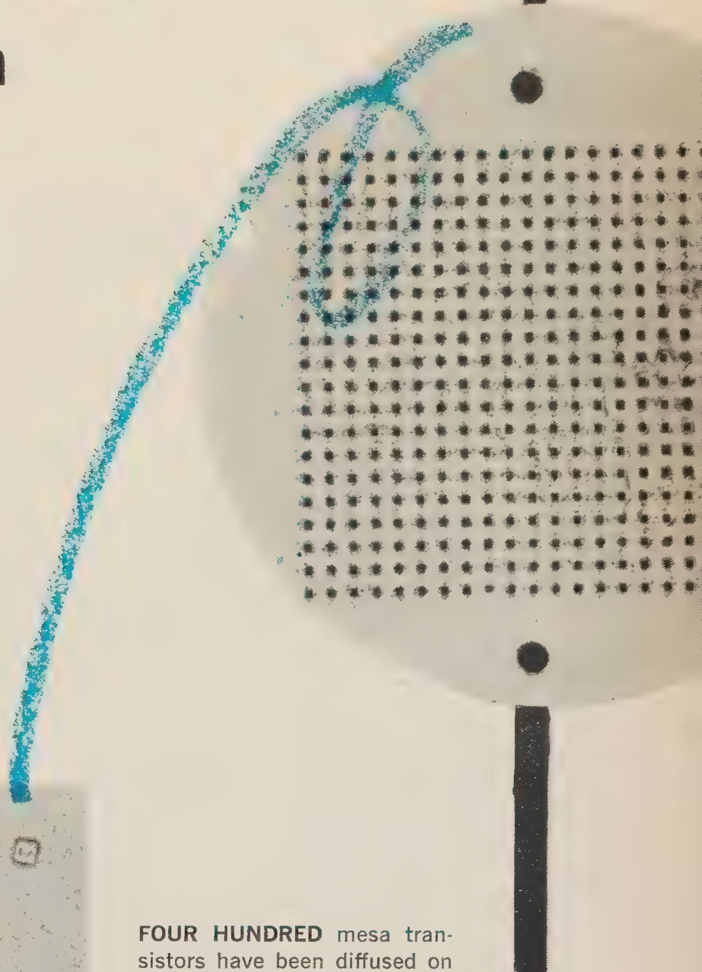
Naturally we realize that correlations like this one may break down when you try to apply them. However, we feel this relationship is well worth looking into, and we plan to explore the possibility of designing materials with larger interionic distances than those of bismuth telluride, which is now at the top of the curve.—End

(3) H. J. Goldsmid, p. 218, *Proc. Phys. Soc. 68*, '55.

Diffusion promises more efficient semiconductor production

- Process can be closely controlled
- Better lead attachment sought
- Zone refining used for germanium

by James Holahan, Electronics Editor



FOUR HUNDRED mesa transistors have been diffused on this single slide of silicon. "Dots" (shown actual size at left) are later cut out of the silicon. After processing and lead attachment, they are packaged in their containers for final tests.

PROBABLY MORE quality transistors and semiconductor diodes are used in aerospace electronics than in any other segment of the electronics industry. The trend to solid-state aerospace components has literally turned into an avalanche. Undoubtedly it won't stop until all but special-purpose active electronic elements in military and commercial aerospace vehicles and their ground equipment are solid-state devices.

However, before semiconductors can reach their full potential, we must be able to turn them out in large volume, with uniform characteristics, and at low cost. These requirements make mechanized manufacture a necessity.

Over a million transistors will be produced this year—but on most of them the processing and assembly operations will still be done manually. Go to any semiconductor production plant and you find that most of

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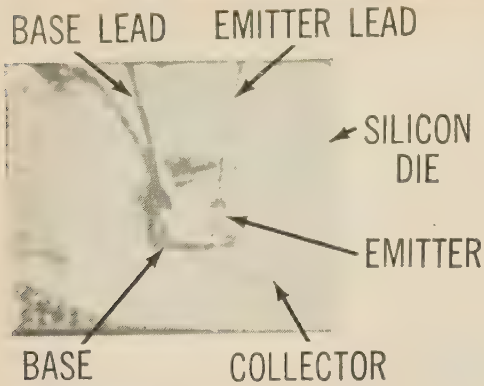

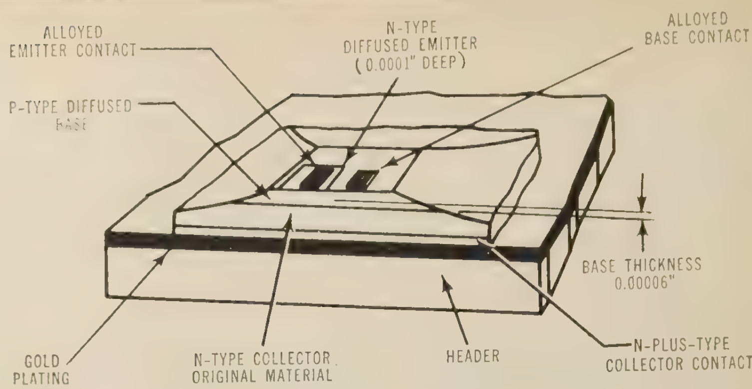

DIFFUSED MESA TRANSISTOR, enlarged about 200 times. Silicon rectangle in center of photo is collector region onto which both base and collector have been diffused (as shown in schematic). Diffusion techniques permit close control of transistor characteristics during manufacture. Part of junction between base layer and N-type parent material is etched away to reduce collector capacitance and produce a mesa-like structure.

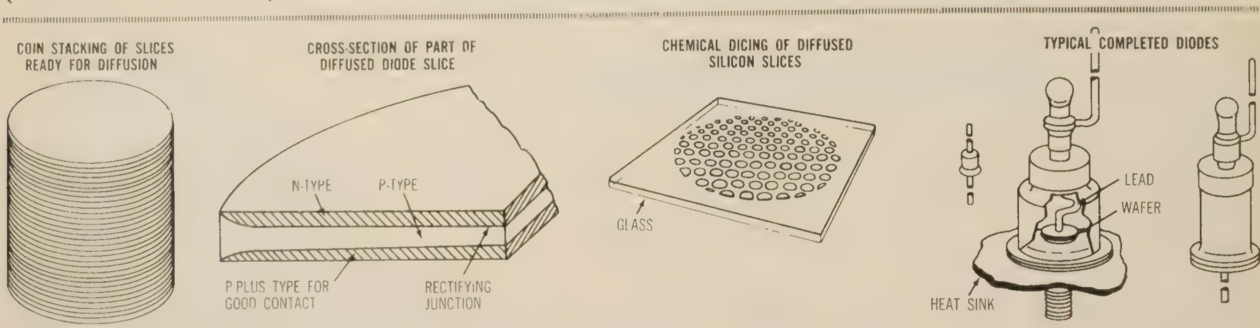

FIGURE 1: Manufacturing steps for diffused power diodes. All drawings except for the wafer cross-section show actual sizes.

its work is performed by skilled and semi-skilled technicians. Many of these have to use microscopes, micromanipulators, and other mechanical aids to see and handle the tiny parts with which they have to work.

Despite the best efforts of production engineers semiconductor manufacture today is slow and expensive. Yields vary because of the unpredictability of many processes and the day-to-day variables introduced by human operators.

Incongruously, the greatest barrier to mechanical production is the rapid advance of the solid-state technology, which simply refused to stand still long enough for the manufacturer to mechanize extensively. Those companies that have been bold enough to devise machines for certain processes are finding that new developments are making these machines obsolete almost before they are broken in. (Testing is an exception. Here, manufacturers have found, automatic devices are far less perishable than on the production lines.) What the manufacturers are looking for is a design plateau—a period of stability in the development of the technology that will let them mechanize with some assurance that they will get a reasonable return on their investment in new machinery.

To the user of semiconductors, the circuit designer, mechanized production means devices with uniform characteristics from lot to lot, higher reliability, quicker delivery, and lower costs. Judging from the complaints of engineers, these improvements are all badly needed for semiconductors used in aerospace electronics.

Diffusion may furnish the design plateau for which all have been looking. Many companies, including Bell Labs, believe there is enough design flexibility in the diffusion process to provide for nearly all foreseeable transistor and diode needs. Bell estimates that diffused silicon and germanium transistors and silicon diodes will be used far more widely than any other semiconductors over the next decade (*see S/A, "What's Ahead for Junction Transistors?", Oct. '59, p. 217).* Western Electric's semiconductor production plant at Allentown, Pa., is turning its emphasis from germanium alloy types to diffused germanium and silicon mesas and silicon diodes. Throughout the semiconductor industry a number of diffused-base and diffused-base-and-emitter transistors is being produced in both silicon and germanium.

In diffusion, impurities are injected under high temperature into the semiconductor material to form the base layer or both base and emitter layers. The semiconductor into which the impurities are injected has enough impurities of its own so that it can serve as the collector element of the transistor. The junction is formed along a line at which the diffused impurities overcome the effect of the original impurities in the solid.

Typical diffusants are gallium and boron (both P-type) and antimony and phosphorus (both N-type). While in the vapor phase, they are diffused into the solid within a special furnace (*Fig. 2*).

The distribution of the impurities is not uniform. It varies with the degree of penetration into the solid and in some cases produces internal electric fields.

These accelerate the minority carriers in transit across the base region, and so very high frequency amplifying and high speed switching transistors can be designed—amplification up to 1000 mc and switching in millimicroseconds become possible. Another advantage of diffused semiconductors is that the junction area can be made quite large, so that the devices can be designed to handle powers up to 100 W and more.

For the manufacturer, the prime attraction of diffusion is that the process can be predicted quite accurately. Both diffusion depth and the amount of impurities that is introduced therefore can be tightly controlled.

Figure 1 shows the important steps in solid-state power diode production as it has been worked out at Western Electric. For a diffused silicon mesa, WE estimates, there are some 40 manufacturing steps. Some of the basic ones are (with NPN silicon):

- An N-type silicon crystal is sliced, and each of its slices is polished to a mirror finish. (Each slice potentially contains 50-1000 transistors, depending on the type of device being made.)
- Each slice is heavily oxidized.
- Gallium vapor is deposited on the slices in a furnace. The result is a P-layer of 0.00016 in. penetration on all surfaces of the slice. (The rate of diffusion is a function of furnace temperature. WE uses 1150±5 deg C for silicon and 650±5 deg C for germanium.)
- The bottom layer of each slice is lapped off to a precise thickness.
- A proto-resist pattern is applied to protect all of the top surface of each slice except for a 0.004x0.006-in. rectangular emitter aperture.
- To get the emitter, phosphorus is diffused in the aperture of the already diffused base layer to a depth of 0.0001 in. This leaves a base layer of 0.00006 in.
- The elements are precisely masked, and metal contact strips are evaporated on the emitter and base layers.
- By masking, a wax dot is placed over the emitter-base contact area to protect it against etching.
- A portion of the collector is etched away to reduce the collector capacitance. (This result is the shoulder-like structure that gives the mesa its name.)
- Each slice is cleaned, scribed, and diced into transistor elements.
- Leads are attached to the elements; each element is attached to a header packaged, degassed and sealed; and each transistor is tested.

Problems are still not all solved

There are many problems still to be solved in the design and production of diffused semiconductors, according to the Bell Lab engineers working at WE's Allentown plant. They feel that diffused semiconductor production is still in its infancy. The main problems are posed by the choice of diffusants, and diffusing cycles and atmospheres, in geometry control, and in lead attachment. Surface stabilization and cleanliness are also causing trouble, but that's hardly news—we have already had to face these two problems on alloy junction devices (and still have to find satisfactory answers).

For lead attachment, WE uses a thermocompression bonding process developed at Bell Labs. By applying a 300-deg C temperature and a pressure of 20,000 psi, it welds lead wires to the base and emitter stripes. While its process does the job, WE reports, it is cumbersome and time-consuming. To get higher production rates, Bell Labs and WE engineers are working on a mechanized version of the process.

On the plus side, the diffused technique allows much wider temperature control than there is in alloying (for which the temperature has to be within one degree C at 500 deg C). Layer thicknesses are easier to control, too, since you are working from one surface only.

A single diffusion furnace of the type shown in *Figure 2* can turn out 30-40 slices in an eight-hour day. This could mean a production rate of as many as 30,—40,000 semiconductors per day.

According to Bell Labs engineers, the yield on certain semiconductor types at the Allentown plant is better than 50 per cent from dicing to final shipment.

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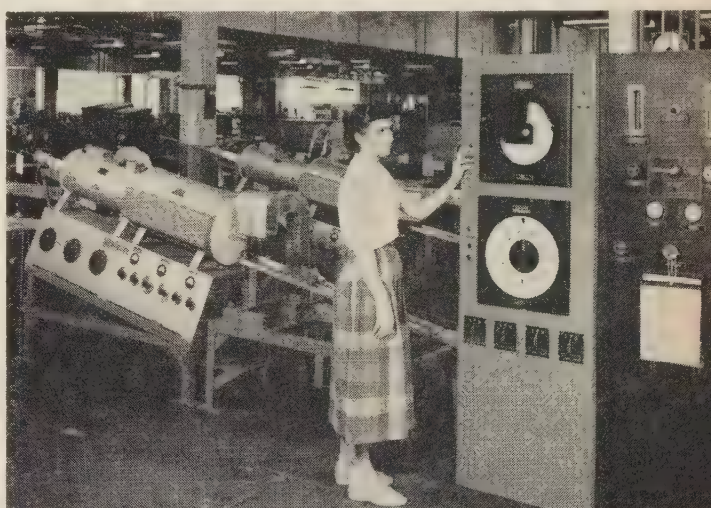
FIGURE 2: Hydrogen furnaces and controls at Western Electric's Allentown, Pa., semiconductor manufacturing plant. Impurities are diffused onto semiconductor (silicon or germanium) surfaces within the furnace. Diffusion depths and impurity concentrations are determined largely by temperatures, times, and carrier gas compositions.



VACUUM PUMP STATION at WE's Laureldale, Pa., semiconductor plant. It removes air from assembled transistors and simultaneously seals them.

Sharply controlled batch processing accounts for this high figure, they say. They hope to improve yields further by introducing statistical quality control and eliminating judgment by the human operator as much as possible.

The failure rate on production units is determined by high temperature testing. On one germanium switching transistor, a statistical sample of 1063 units is aged at 100 deg C for 1000 hours. If the entire lot is to pass, there may be no more than two failures. (By definition, a failure occurs when any of a large number of end point limits is exceeded).

This test enables WE to say with 90 per cent confidence that the failure rate of the production lot is less than 0.5 per cent per 1000 hours at 100 deg C. The test results can be interpolated down to room temperature.

Purifying germanium and silicon

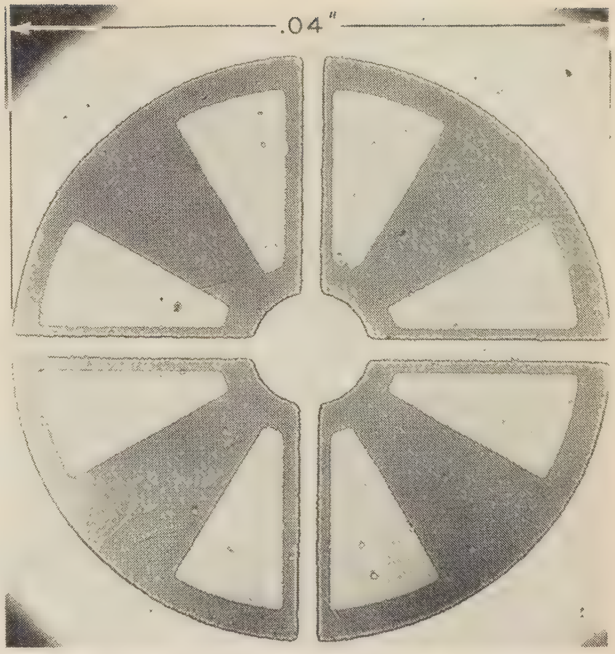
Regardless of the method used to produce transistors, the crystal has to be extremely pure. Manufacturers are able to purify germanium and silicon to one part of impurity per 10^9 parts of the material. (This applies for impurities due to the elements in groups 3 and 5 of the periodic table, copper, iron, and other common metals. It does not apply for gaseous impurities.)

In germanium, the purity problem has been solved by "zone refining", another technique developed at Bell Labs (*Fig. 3*). Within a graphite or quartz container, the germanium is slowly moved through a horizontal tube around which are wound RF induction heating coils spaced in different "zones" along the tube. The atmosphere within the tube is inert, and the container in which the germanium is placed does not react with the metal.

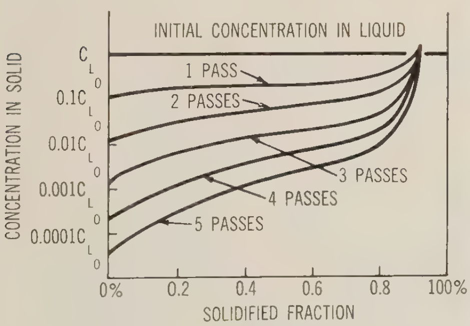
As the germanium is moved through the tube, it is alternately melted and frozen. The highly pure metal tends to freeze more quickly than the impurities, so that these can be separated out. The metal may be passed through the zone refiner several times to get higher purities.

Unfortunately, horizontal zone refining in crucibles does not work for silicon—there aren't any known containers with which silicon will not react.

A technique known as floating-zone purification is being used with some success with silicon. However it is slow and expensive and seems limited to special-purpose devices like high power rectifiers.—End



STRUCTURE of stepping transistor made by Bell Labs from a single piece of silicon by oxide masking diffusion. Photo is magnified about 100 times. Light and dark areas are different electrically active regions.



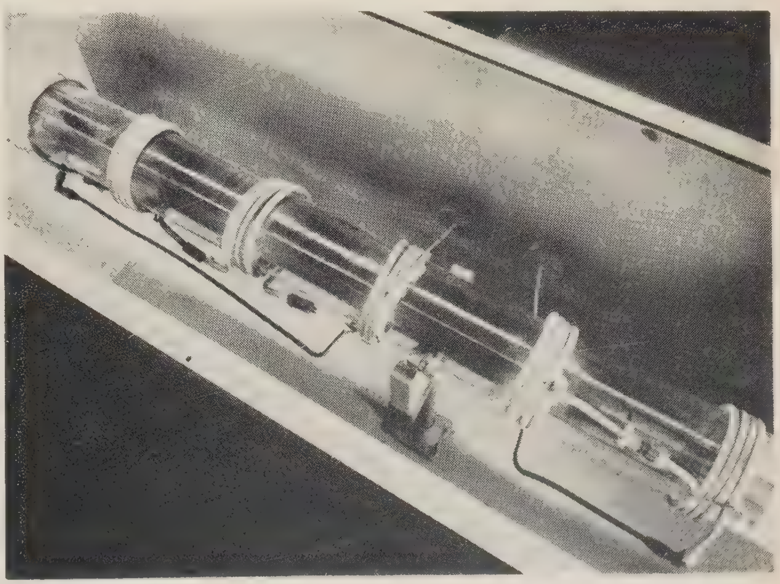


FIGURE 3: Zone refining is universally used for germanium purification. Molten germanium is slowly drawn past induction heating coils. Purity following each pass is shown in the graph.

Electronic materials reference file

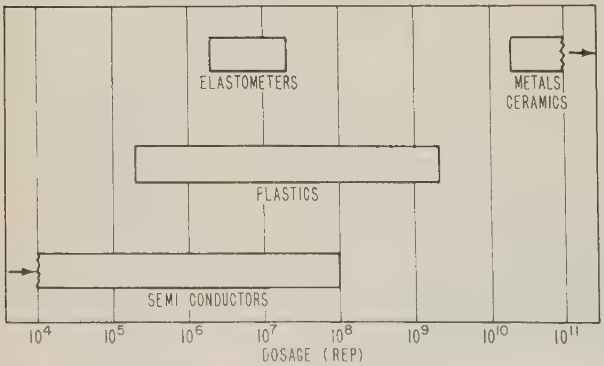
● Radiation ● Semiconductors ● Foams ● Electric Properties

THIS REFERENCE FILE presents data on the radiation stability of electronic materials, on semiconductor materials, and on plastic foams for aerospace electronics, as well as a solid-state periodic table.

The *radiation stability* bar graph shows the relative stability of the physical properties of major types of materials in radiation fields containing 10 rep gamma photons for each rep of neutrons. Designers and users of electronic components must find out whether required operating environments might produce permanent radiation effects that could affect component reliability. The GE report from which this graph is taken points out that more component failures are due to permanent changes in the physical properties of materials that are caused by radiation than to transient or reversible damage. Permanent changes depend primarily on the material type, the amount and type of radiation, and environmental conditions such as temperature and atmosphere.

This graph was prepared by Atomic Products Div., General Electric Co., Cincinnati, Ohio, as part of Estimated Radiation Stability of Aircraft Components."

Radiation Stability



The *solid-state periodic table* is a rearrangement of the periodic table of the chemical elements that makes it easier to study the electric nature and behavior of materials. The key to the table is given in the lower right-hand box of the first section, with "X" representing electronegativity, defined as the extent, relative to other atoms, to which a given atom or group of atoms tends to attract and hold valence electrons in its immediate vicinity. "Outer orbital shift" indicates that the electron that differentiates one element from another is in the outer electron shell of the atom. "Second orbital shift" indicates that this electron is in the second shell from the outer most one and so on.

This table was prepared by the Research Laboratory, Servomechanisms, Inc., Santa Barbara, Calif.

Graph 1 on *semiconductor materials* shows the maximum temperatures at which semiconductors made of various materials can be expected to operate. In the first column are semiconductors that occur as elements; in the second, those in which two of these elements are combined. The three remaining columns show compounds made up of elements in the third and fifth columns of the periodic table.

Carbon (C) refers to diamond, which has not yet been grown with sufficient control so that practical semiconductors could be made from it. Germanium (Ge) and silicon (Si) are the only elementary semiconductor materials now in use. They can be alloyed in any proportion, so that their combinations have a range of properties whose limits are the values for the two elements used by themselves.

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Solid-State Periodic Table

TYPICAL ELEMENTS—Outer Orbital Shift

1 H 1.008 $1s^1$ -259 hcp 2.13 (1)2.08 (1)proton 0.000-							**2 He** 4.003 $1s^2$ -271.4 hcp
3 Li 6.940 $2s^1$ 186 bcc 0.95 (1)0.70	**4 Be** 9.013 $2s^2$ 1280 hcp 1.45 (2)0.30 (3)0.20	**5 B** 10.82 $2s^2 2p^1$ 2300 orth 1.9 (3)0.20	**6 C** 12.011 $2s^2 2p^2$ 3700 h 2.55 (4)2.60 (4)0.15	**7 N** 14.008 $2s^2 2p^3$ -210 h 2.98 (3)1.71 (3)0.16 (5)0.15	**8 O** 16.0000 $2s^2 2p^4$ -218 c 3.45 (2)1.35 (6)0.09	**9 F** 19.00 $2s^2 p^5$ -223 3.95 (1)1.33 (7)0.07	**10 Ne** 20.183 $2s^2 2p^6$ -249 fcc
11 Na 22.991 $3s^1$ 97.7 bcc 0.90 (1)1.00	**12 Mg** 24.32 $3s^2$ 650 hcp 1.2 (2)0.75	**13 Al** 26.98 $3s^2 3p^1$ 660 fcc 1.5 (3)0.55	**14 Si** 28.09 $3s^2 3p^2$ 1430 dc 1.8 (4)2.71 (4)0.40	**15 P** 30.975 $3s^2 3p^3$ 44 c 2.1 (3)2.12 (3)0.44 (5)0.34	**16 S** 32.066 $3s^2 3p^4$ 119.0 orth 2.53 (2)1.82 (4)0.37 (6)0.30	**17 Cl** 35.457 $3s^2 3p^5$ -101 tet 2.97 (1)1.81 (1) (5)0.26 (7)0.34	**18 A** 39.944 $3s^2 3p^6$ -189.4 fcc
19 K 39.100 $4s^1$ 63 bcc 0.80 (1)1.33	**20 Ca** 40.08 $4s^2$ 850 fcc 1.0 (2)1.05	**31 Ga** 69.72 $4s^2 4p^1$ 29.8 orth 1.4 (3)0.62	**32 Ge** 72.60 $4s^2 4p^2$ 958 dc 1.7 (4)2.72 (2)0.65 (4)0.55	**33 As** 74.91 $4s^2 4p^3$ 814 romb 2.0 (3)1.91 (3)0.69 (5)0.47	**34 Se** 78.96 $4s^2 4p^4$ 220 h 2.4 (2)1.93 (4)0.50 (6)0.42	**35 Br** 79.916 $4s^2 4p^5$ -7.2 orth 2.75 (1)1.96 (5)0.47 (7)0.39	**36 Kr** 83.80 $4s^2 4p^6$ -157 fcc
37 Rb 85.48 $5s^1$ 39 bcc 0.78 (1)1.49	**38 Sr** 87.63 $5s^2$ 770 fcc 1.0 (2)1.18	**49 In** 114.82 $5s^2 5p^1$ 156.4 tet 1.4 (3)0.92	**50 Sn** 118.70 $5s^2 5p^2$ 231.9 tet 1.7 (4)2.94 (2)1.02 (4)0.65	**51 Sb** 121.76 $5s^2 5p^3$ 630.5 romb 1.8 (3)2.08 (3)0.90 (5)0.62	**52 Te** 127.61 $5s^2 5p^4$ 450 h 2.1 (2)2.12 (4)0.89 (6)0.56	**53 I** 126.91 $5s^2 5p^5$ 114 orth 2.45 (1)2.20 (5)0.94 (7)0.50	**54 Xe** 131.30 $5s^2 5p^6$ -112 fcc
55 Cs 132.91 $6s^1$ 28 bcc 0.75 (1)1.70	**56 Ba** 137.36 $6s^2$ 704 bcc 0.9 (2)1.38	**81 Tl** 204.39 $6s^2 6p^1$ 300 hcp 1.3 (1)1.49 (3)0.95	**82 Pb** 207.21 $6s^2 6p^2$ 327.3 fcc 1.5 (4)2.00 (2)1.18 (4)0.70	**83 Bi** 209.00 $6s^2 6p^3$ 271.3 romb 1.8 (3)2.13 (3)1.20 (5)0.74	**84 Po** 210.00 $6s^2 6p^4$ 254 m 2.0 (6)0.67	**85 At** 211 $6s^2 6p^5$ (7)0.62	**86 Rn** 222.00 $6s^2 6p^6$ -71 fcc
87 Fr 223 $7s^1$ bcc 0.72 (1)1.80	**88 Ra** 226.05 $7s^2$ 700 0.9 (2)1.42					LEGEND:	Atomic Number X ELEMENT (1)Valence Ion Radii At.Wt. Valence Electrons M.P. crystal struct. common form

RELATED METALS—Second Orbital Shift

21 Sc 44.96 $3d^1 4s^2$ 1200 fcc 1.3 (3)0.83	**22 Ti** 47.90 $3d^2 4s^2$ 1820 hcp 1.6 (2)0.76 (3)0.70 (4)0.60	**23 V** 50.95 $3d^3 4s^2$ 1735 bcc 1.9 (2)0.88 (3)0.75 (4)0.59 (5)0.57	**24 Cr** 52.01 $3d^5 4s^1$ 1930 bcc 2.2 (2)0.89 (3)0.70 (6)0.52	**25 Mn** 54.94 $3d^5 4s^2$ 1245 c 2.6 (2)0.83 (3)0.62 (4)0.52 (7)0.46	**26 Fe** 55.85 $3d^6 4s^2$ 1539 bcc (2)0.80 (3)0.67	**27 Co** 58.94 $3d^7 4s^2$ 1492 hcp (2)0.78 (3)0.65	**28 Ni** 58.71 $3d^8 4s^2$ 1453 fcc (2)0.74 (3)0.35	**29 Cu** 63.54 $3d^{10} 4s^1$ 1083 fcc 2.2 (1)0.95 (2)0.70	**30 Zn** 65.38 $4s^2$ 419.5 hcp 1.2 (2)0.83
39 Y 88.92 $4d^1 5s^2$ 1490 hcp 1.3 (3)0.95	**40 Zr** 91.22 $4d^2 5s^2$ 1750 hcp 1.6 (4)0.80	**41 Nb** 92.91 $4d^4 5s^1$ 2415 bcc 1.8 (4)0.67 (5)0.69	**42 Mo** 95.95 $4d^5 5s^1$ 2625 bcc 2.1 (4)0.68 (6)0.65	**43 Tc** 99 $4d^5 5s^2$ 2140 hcp 2.4 (7)0.56	**44 Ru** 101.1 $4d^7 5s^1$ 2500 hcp (4)0.60	**45 Rh** 102.91 $4d^8 5s^1$ 1960 fcc (3)0.75 (4)0.65	**46 Pd** 106.4 $4d^{10}$ 1552 fcc (2)0.80 (4)0.65	**47 Ag** 107.88 $5s^1$ 960.8 fcc 1.9 (1)0.97 (2)0.89	**48 Cd** 112.41 $5s^2$ 320.9 hcp 1.1 (2)0.99
57 La 138.92 $5d^1 6s^2$ 826 hcp 1.2 (3)1.15	**72 Hf** 178.50 $5d^2 6s^2$ 1700 hcp 1.3 (4)0.86	**73 Ta** 180.95 $5d^3 6s^2$ 2996 bcc 1.4 (5)0.73	**74 W** 183.86 $5d^4 6s^2$ 3380 bcc 2.1 (4)0.68 (6)0.65	**75 Re** 186.22 $5d^5 6s^2$ 3170 hcp (4)0.72 (7)0.56	**76 Os** 190.2 $5d^6 6s^2$ 2700 hcp (4)0.88 (6)0.69	**77 Ir** 192.2 $5d^7 6s^2$ 2443 fcc (4)0.65	**78 Pt** 195.09 $5d^9 6s^1$ 1769 fcc (2)1.06 (4)0.96	**79 Au** 197.0 $5d^{10} 6s^1$ 1063 fcc 2.3 (1)1.37 (3)0.85	**80 Hg** 200.61 $6s^2$ -38.87romb 1.0 (1)1.27 (2)1.12
89 Ac 227. $6d^1 7s^2$ 1600 1.0 (3)1.18									

RARE EARTHS—Third Orbital Shift

(Electronegativity 1, 2+)

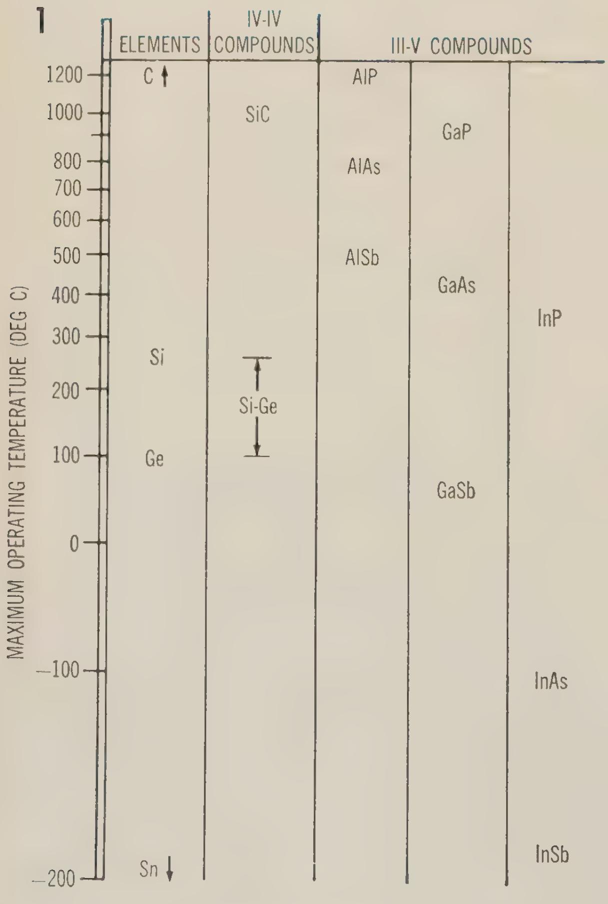
(Ionic Radii; (3) 1.09±05, (4) 0.99±05)

58 Ce 140.13 $4f^2 6s^2$ 600 fcc	**59 Pr** 140.92 $4f^3 6s^2$ 940 hcp	**60 Nd** 144.27 $4f^4 6s^2$ 840 hcp	**61 Pm** 145. $4f^5 6s^2$ h	**62 Sm** 150.35 $4f^6 6s^2$ 1300 h	**63 Eu** 152.0 $4f^7 6s^2$ bcc	**64 Gd** 157.26 $4f^7 5d^1 6s^2$ hcp	**65 Tb** 158.93 $4f^9 6s^2$ 327 hcp	**66 Dy** 162.51 $4f^{10} 6s^2$ hc	**67 Ho** 164.94 $4f^{11} 6s^2$	**68 Er** 167.27 $4f^{12} 6s^2$	**69 Tm** 168.94 $4f^{13} 6s^2$ hc	**70 Yb** 173.04 $4f^{14} 6s^2$ fcc	**71 Lu** 174.99 $5d^1 6s^2$ hc
90 Th 232.05 $6d^2 7s^2$ 1800 fcc	**91 Pa** 231 $5f^2 6d^1 7s^2$ 3000	**92 U** 238.07 $5f^3 6d^1 7s^2$ 1133 orth	**93 Np** 239 $5f^4 6d^1 7s^2$ 640 orth	**94 Pu** 242 $5f^5 6d^1 7s^2$	**95 Am** 243 $5f^7 7s^2$ 850	**96 Cm** 243 $5f^7 6d^1 7s^2$	**97 Bk** 245 $5f^8 6d^1 7s^2$	**98 Cf** 246 $5f^9 6d^1 7s^2$	**99 E** 253	**100 Fm** 255	**101 Mv** 256	**102 No**	**103**

Class	Epoxy		Urethane		
	Amine-Cured, Rigid	Anhydrine-Cured, Rigid	Rigid	Semi-Rigid	Flexible
Physical Characteristics					
Available densities (lb/cu ft)	3–38	6–8	1–50	2–22	1.5–8
Compressive strength @ 8 lb/cu ft	330[A]	110	240[B]	150[B]	0.3–0.6[B, C]
Compressive modulus @ 8 lb/cu ft	10,500[A]		8500	3000	2–10[C]
Flexural strength @ 8 lb/cu ft	400[A]		200–300		
Flexural modulus @ 8 lb/cu ft	8300[A]		6000		
Tensile strength @ 8 lb/cu ft	320[A]	76	300	140	15–30[C]
Thermal conductivity @ 8 lb/cu ft (btu-in.-deg F^{-1}-sq ft^{-1}-he^{-1})	0.25[A, J]	0.24	0.20–0.32	0.33	0.20[C]
Coefficient of thermal expansion ($\times 10^{6}$)	40–60		30–40	40–45	
Max operating temperature (deg F)	200–300	240	250–400	150–250	200–250
Electrical Characteristics					
Dielectric strength (V/mil)		85	40–75	35–50	
Volume resistivity (ohm-cm)		$>10^{12}$	10^{13}–10^{15}	10^{12}–10^{15}	
Dielectric constant @ 8 lb/cu ft	1.15[A]	1.5	1.15	1.2	1.05[C]
Dissipation factor @ 8 lb/cu ft	0.0004[A]		0.0003	0.0004	0.0003[C]
Processing					
Special equipment required	no	no	no	no	no
Resin viscosity (centipoises or form)	1,–15,000	powder	15,–300,000	8,–25,000	200–20,000
Processing temperature (deg F)	75–225	175–225	75–150	75–100	75
Pot life at processing temperature (min)	30–40	30–60	0.5–3	0.5–7	0.1–2.0
Relative exotherm temperature	very high	low	moderate to high	low to moderate	low
Number of components	2	1	2	2	2 or 3
Postcure required	no	yes	varies	no	varies
General					
Relative cost	moderate to high	moderate to high	moderate	moderate	moderate
Primary feature or application	good strength, high exotherm	easily processed	high strength, versatility, low K factor when freon blown	low exotherm compared with rigid	shock absorption

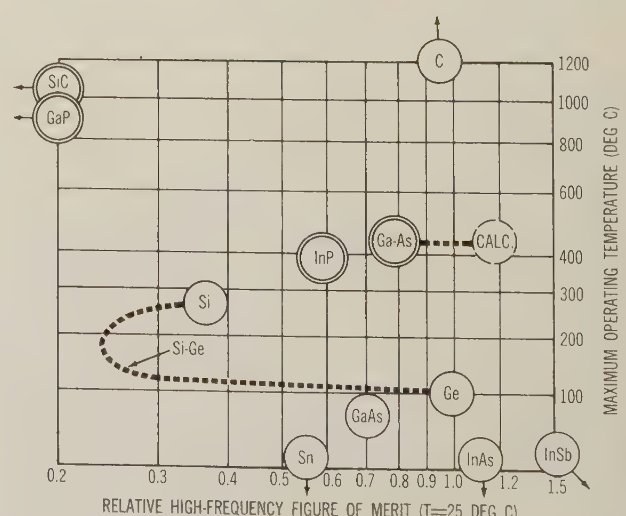
(A) At 10 lb/cu ft density. (B) At 25 per cent deflection. (C) At two lb/cu ft density. (D) At 20 lb/cu ft density. (E) At 21 lb/cu ft density. (F) At five per

1



Semiconductor Materials

2



for Aerospace Electronics

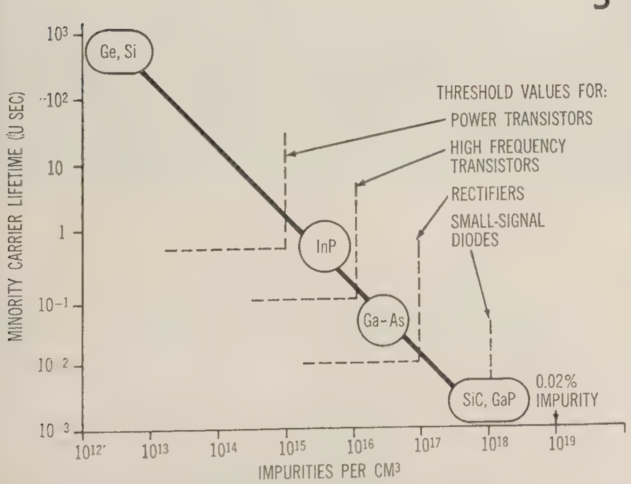
Syntactic Epoxy-Amine, Rigid	Syntactic Epoxy-Anhydride, Rigid	Polystyrene Rigid	Silicone Rigid	Silicone Flexible	Polyester Rigid	Phenolic Rigid	Vinyl Rigid	Vinyl Flexible	Cellulose Acetate Rigid
20–40	18–23	1–15	10–18	20–25	2–20	0.3–60	2–26	1.5–7.5	4–8
1010^D	2700^E	140^F	200^G	12.2^B, H	160	150^A	100	7^B	235^I
800^D	2200^E	260				22,800			13,500
54,000^D					230				177
									5500
		147		60^H	100	45	250		183
0.38^D	0.30^E	0.27	0.3^G	0.4–0.6^H	0.20–0.30	0.46	0.36	0.28^B	0.32
40	17	30–40			40–50				25
300	500	185	>500	500	300	350	200	175	350
		48		24^H					
		4×10^{13}		1.8×10^{13}^H					
1.45^D	1.5^E	1.12	1.25^G	2.8	1.1	1.20	1.20		1.10–1.12
×0.01^D	0.01^E	0.0005	0.0008			0.029			0.002–0.003
no	no	recommended	no	no	yes	no	depends on type	depends on type	yes, sold prefoamed
viscous liquid	damp sand	beads	powder	40,000	8500	viscous liquid	liquid	liquid	
75 up	250 up	230 up	300–355	75	75	75	300–400	300–400	
480^K				30	7				
low	low	none		none	moderate to high		none	none	none
2	1 or 2	1	1	2	2 or 3		1 or 2	1 or 2	
yes	yes	no	yes	24 hr^L	recommended		no	no	
high	high	low	high	high	low	low	low	low	high
pack-in-place	pack-in-place	good moisture barrier	heat stability	heat stability	low cost, friable, applied as ungelled foam	low cost; extremely low densities available		excellent shock absorption	prefoamed sandwich construction,

...lection. (G) At 14 lb/cu ft density. (H) Over range of available densities. (I) At yield point. (J) 0.11 with freon blowing. (K) At 75 deg C. (L) At room temperature.

The aluminum compounds in the third column tend to decompose in the presence of moisture and haven't been used very successfully as yet.

Graph 2 shows operating temperature limits and a high frequency figure of merit relating to the suitability of various materials for transistors. The more interesting compounds are identified by double circles.

3



The Si-Ge mixture gives poorer high frequency performance than either silicon or germanium, so it's not of much interest. Gallium arsenide (GaAs) and indium phosphide (InP) should have frequency responses comparable to those of Si and Ge, yet they operate at higher temperatures. Silicon carbide (SiC) and gallium phosphide (GaP) don't operate at frequencies high enough for transistor use; however, they may be useful for rectifiers at very high temperatures.

Graph 3 shows how far along we are in purifying semiconductor materials. It plots impurity concentration vs minority carrier lifetime, on which a device's performance largely depends. Of the materials available today, only G and S are practical for use in power transistors. Improvements in the art should continue to move the compound materials up the curve toward G and S.

These graphs were prepared by William M. Webster, Director, Electronic Research Laboratory, RCA Laboratories, Princeton, N.J.

The table on *plastic forms for aerospace electronics* gives the physical, electric, and processing characteristics of various plastic foams. Important applications of foams in aerospace electronics are in secondary structures and encapsulation, vibration isolation, and thermal insulation. With the help of this table, you can find the proper foam for your particular requirement.

This table was prepared for SPACE/AERONAUTICS *by Lawrence V. Gallacher, Development Services Dept., Arma Div., American Bosch Arma Corp., Garden City, N.Y.*

PROBLEM:

Measure angular acceleration accurately

ANSWER:

The New Donner Angular Accelerometer

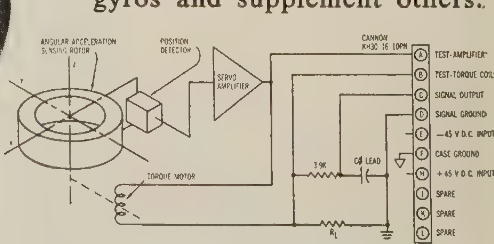
Light

Compact

High natural frequency

THE FACTS...As you are well aware, designing a good angular accelerometer is a tough technical task. Donner Scientific's new unit is another successful chapter in a record of creative engineering.

Chief applications for this unique force balance angular accelerometer are closing the servo loop on ground launching equipment for missiles and detecting the roll, pitch and yaw accelerations of missiles once they are airborne. In the latter application, the Model 4525 can replace some gyros and supplement others.



Operational diagram of Donner's new Model 4525 Angular Accelerometer.

Donner's rugged new angular accelerometer weighs only 2 pounds.

The Specs

RANGES AVAILABLE
From ±1 radian/sec² to ±50 rad/sec² to any intermediate range.
FREQUENCY RESPONSES
±1 rad/sec² 30 cps natural frequency (90° lag)
±10 rad/sec² 100 cps natural frequency (90° lag)
OUTPUT, FULL SCALE
±20 volts across a 12,500 ohm load
RESOLUTION 0.01% full scale or better
LINEARITY 0.1% full scale
HYSTERESIS Less than 0.01% full scale
DAMPING 0.6 ± 0.1 of critical
SIZE 3.7" diameter x 3.7" high
WEIGHT 2 pounds

The mechanically rugged and electronically rigid Model 4525 is one more basic technical contribution from an engineering team specializing in inertial systems interlocking time, acceleration, velocity, and other dynamic inputs.

MORE DATA AVAILABLE—An illustrated 4 page data file is yours for the asking. Please address Dept. 0911.

DONNER SCIENTIFIC COMPANY
CONCORD, CALIFORNIA

Metal oxide additives give

higher-K capacitor ceramics

- "Freak" effect led to new discoveries
- Nickel and iron oxides proved best
- Weight accuracy is important

by F. N. Bradley, Research Engineer,
Materials Section, Aerospace Div., Boeing Airplane Co.*

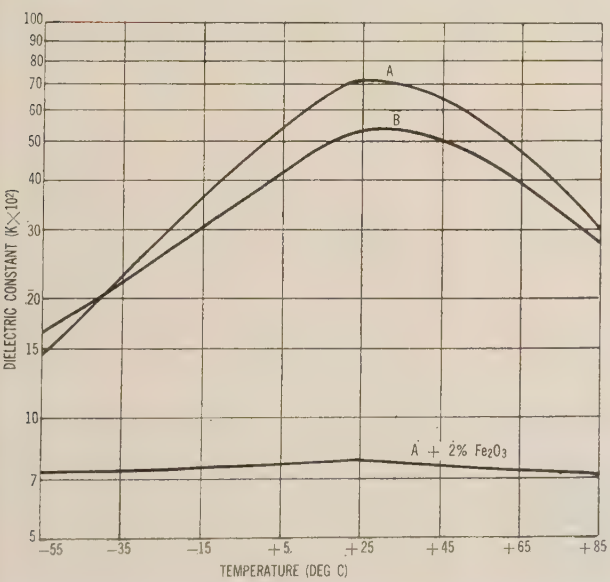
EVER since the discovery of the unique ferroelectric properties of combined barium oxide and titanium oxide ($BaTiO_3$) during World War II, the art of formulating capacitor ceramic compositions with a high dielectric constant *(K)* has been largely empirical. It was to be expected that any required modifications in $BaTiO_3$ would be selected among the same materials that had already been used successfully to alter the titania (temperature-compensating) dielectrics.

Additions of strontium, calcium, magnesium, or lead titanate all produce useful modifications in the temperature-capacitance (T-C) curve of the ceramic. A virtu-

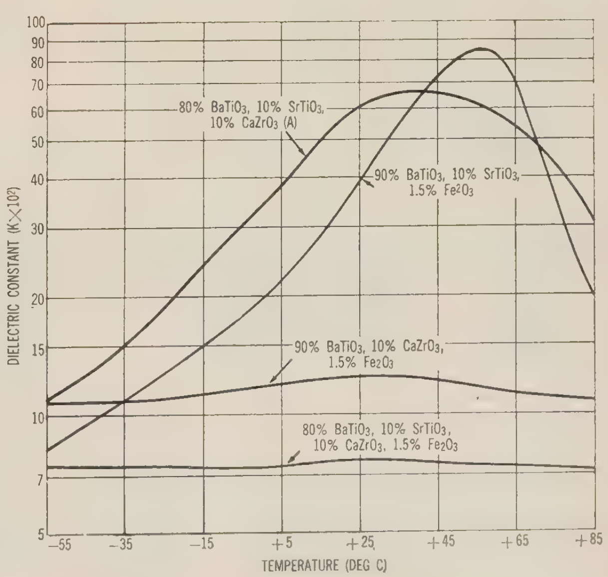
* Aerospace Div., Boeing Airplane Co., Box 3707, Seattle 24, Wash.

more on next page

1 **DIELECTRIC** constant vs temperature for conventional high-K materials (see Table) and "freak" addition of two per cent Fe_2O_3.



2 **DIELECTRIC** constant vs temperature for variations of material A (see Table) tested after the discovery of the "freak" effect of Fe_2O_3.



ally countless number of compositional variations can be created by applying alkaline earth zirconates and stannates, each of which has a somewhat different action. A convenient way of classifying these modifiers is to consider them as either shifters or depressors of the peak dielectric constant.

When the shift and spread effects were first recognized in 1952, many felt the problem had been reduced to that of producing a range of capacitor bodies that sacrifice dielectric constant for the sake of better temperature stability. The *Table* shows two of the more popular high-K compositions in use at that time. In each of these materials, $CaZrO_3$ seems to act partly as a shifter and partly as a peak broadener. Also, it shows fewer depressing effects than the other commonly used compounds.

To improve the vitrification characteristics of material A, it became standard shop practice to add a small amount of Fe_2O_3 (about 0.2 per cent). On one occasion, however, a lab technician mistakenly added two per cent of Fe_2O_3. The error was easily detected because the dielectric constant of the compound dropped to 800, while the capacitance-temperature stability improved to —10 per cent, as against about —30 per cent for the then conventional K800 material (*Fig. 1*).

Materials engineers were quick to take advantage of this unexpected discovery. Systematic variation of the components of the "freak" body at least disclosed the nature of the compound, even though no explanation could be given for the observed effects.

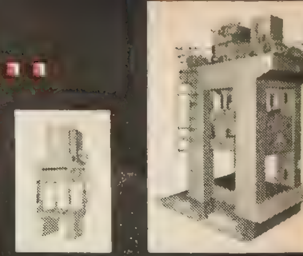
Later on, the elimination of $CaZrO_3$ from the "freak" compound resulted in the sharp peak characteristic of the T-C curve for solid $BaTiO_3$-$SrTiO_3$ solutions. (Adding more Fe_2O_3 to the compound had no visible modifying effects.) On the other hand, eliminating $SrTiO_3$ raised the dielectric constant to 1200, while the highly desirable flatness of the T-C curve was retained (*Fig. 2*).

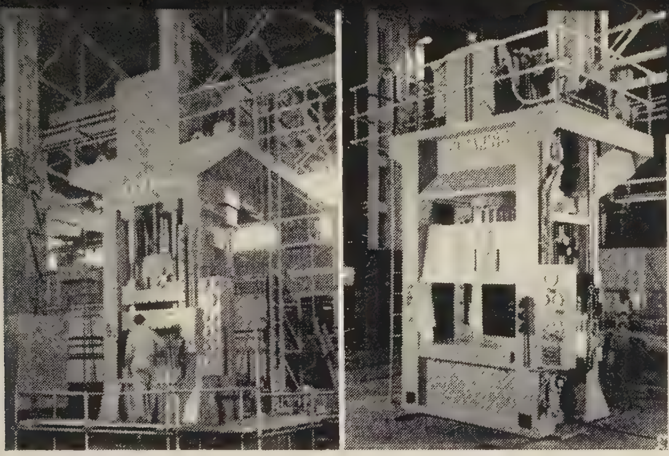
Next the oxides of nickel, chromium, manganese, cobalt, copper, vanadium were substituted for the Fe_2O_3 (*Fig. 3*). The percentage of ferric oxide was also varied. The copper and vanadium oxide additions did not flatten the curve. The manganese and chrome oxides altered the curve somewhat, but

more on page 186

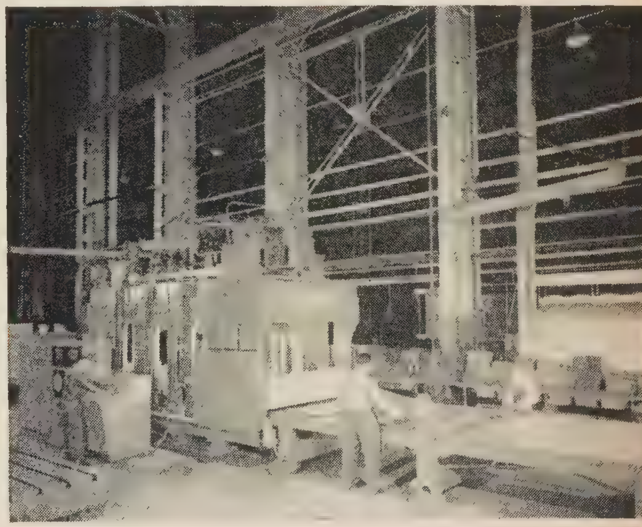
When it comes to Hydraulic Presses...

large or small

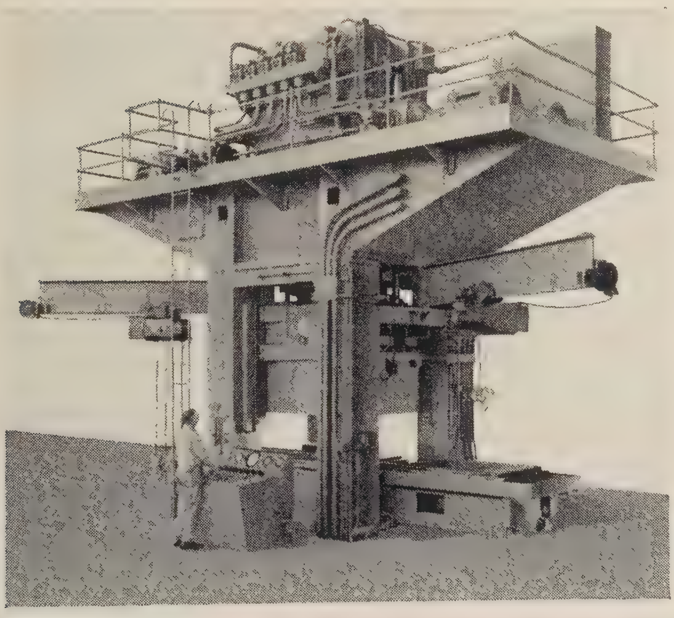




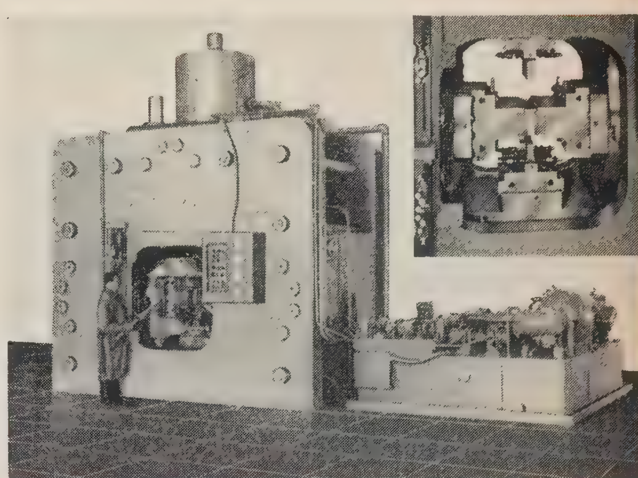
FOR ANY TYPE OF APPLICATION such as these metalworking drawing presses



WITH SPECIAL FEEDING EQUIPMENT as shown on this metal bonding machine



WITH ANY TYPE OF CONTROLS as seen on this rubber pad forming press



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Space Age Milestone!

Man's flight into outer space drew nearer on September 11, 1959 with the successful re-entry of NASA's "Big Joe" test capsule controlled by a Honeywell Stabilization System

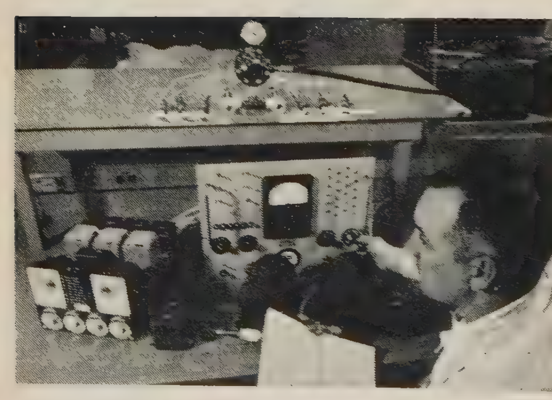
The guidance system for this capsule, launched by an Atlas missile, was provided by Honeywell—and it was delivered in less than half the time usually required for projects of this scope.

Rapid delivery was possible because the basic components necessary to accomplish this sensitive and exacting task were on-the-shelf or in production at Honeywell. However, two critical jobs remained to be done. One was the task of designing a package for these components which would be rugged and exact enough to do the job; and the other was that of providing the ground support for system check-out and pre-launch monitoring. Both of these difficult objectives were completed in the time allowed.

This electronic stabilization and control system is designed to provide a reference that permits measurement of the capsule's attitude and rate of motion. By operating the on-off valves for the reaction control nozzles, it dampens any oscillatory tendencies of the capsule and eliminates the possibility of tumbling.

The design and delivery of this system, the first of six such Honeywell systems for NASA Mercury capsule test shots, is in keeping with the accelerated man-in-space program and is typical of Honeywell's ability to meet both stringent requirements and critical deadlines.

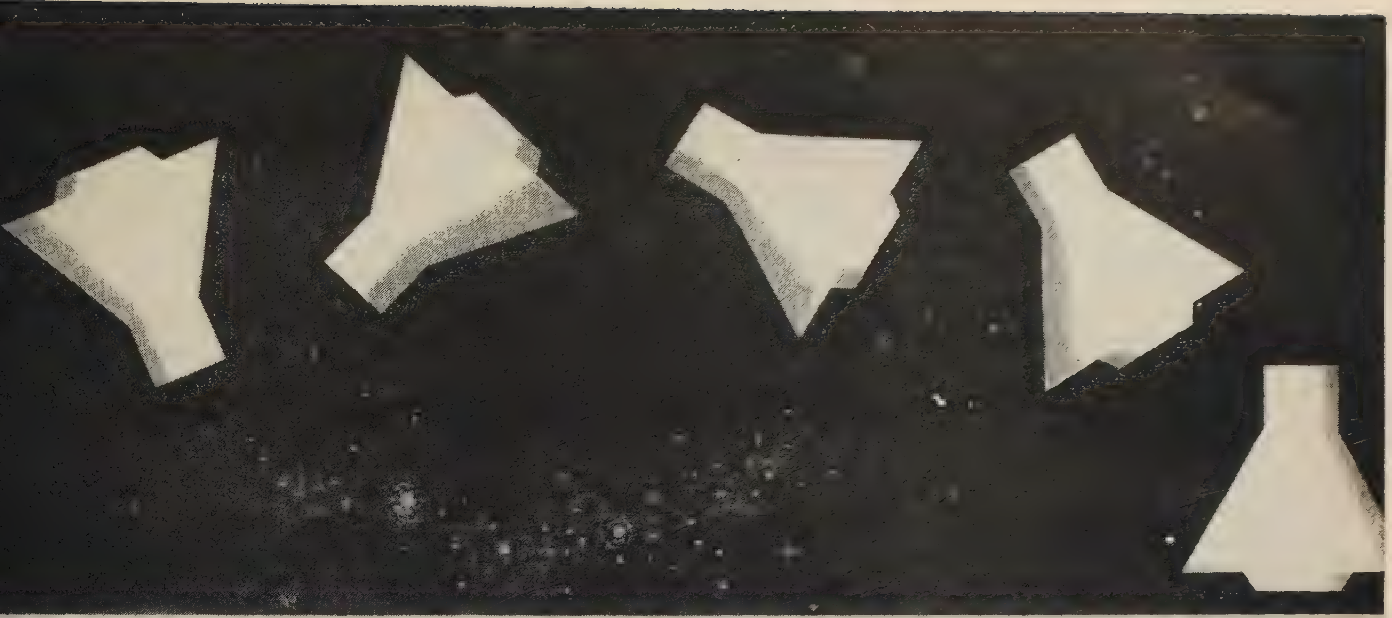
This readiness for the space age stems both from Honeywell's established policy of supporting the national defense and from the company's own historic areas of interest. For further information concerning Honeywell's capability in space age projects, write Minneapolis-Honeywell, Aeronautical Division, Dept. 671, 2600 Ridgway Road, Minneapolis 13, Minn.



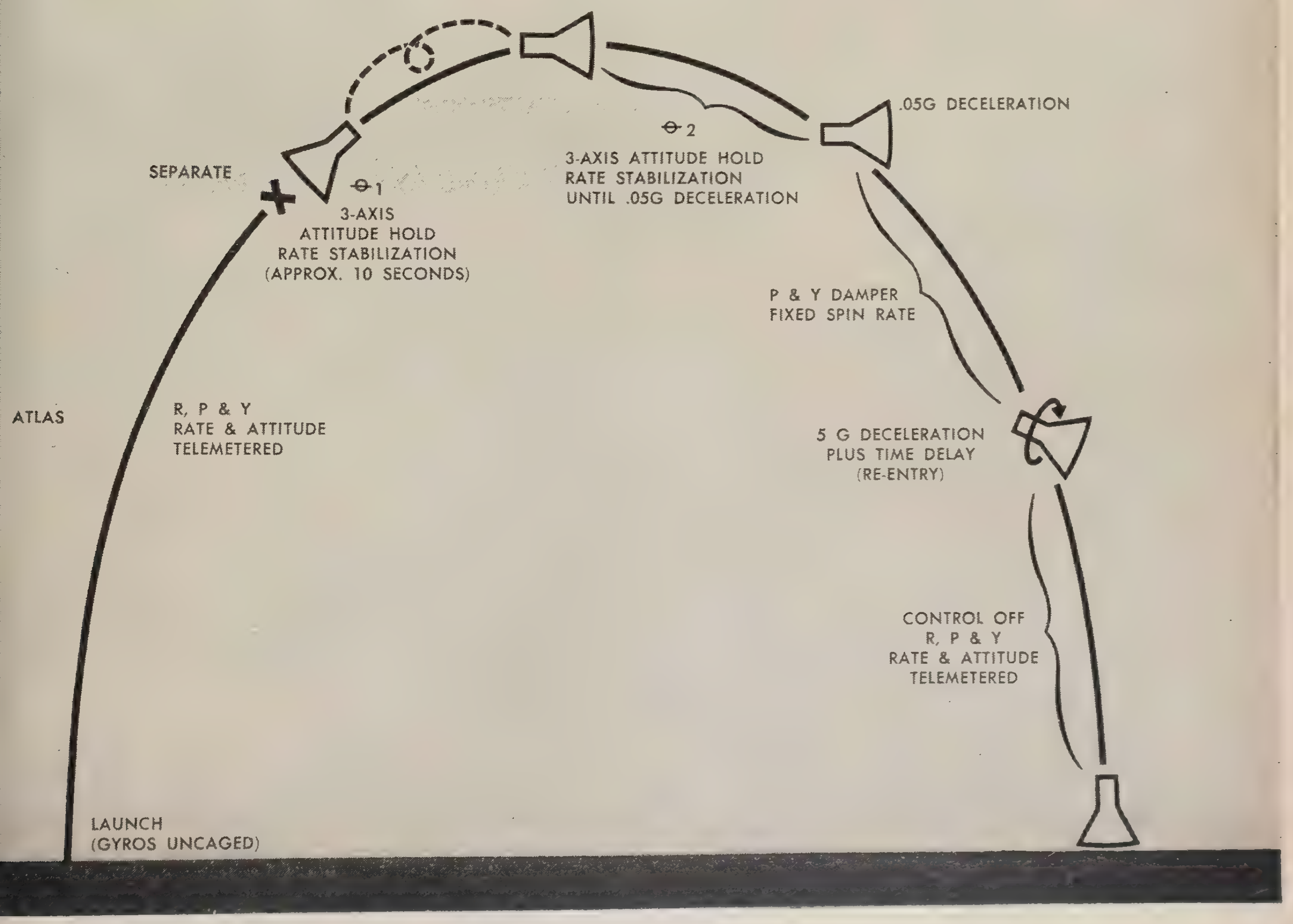
Final check of attitude stabilization control system for flight and re-entry control of "Big Joe" test capsule is made by a Minneapolis-Honeywell technician prior to delivery.

Honeywell

H Military Products Group



The Honeywell "Big Joe" Control System assumes control at separation and immediately provides a three-axis attitude hold, rate-stabilized mode to maintain the separation attitude (Θ_1). Approximately ten seconds later, it programs the capsule to a new attitude (Θ_2), and maintains this attitude until .05g deceleration is sensed, indicating that re-entry is commencing. Upon sensing .05g deceleration, attitude hold shuts off, pitch and yaw rate stabilization are maintained, and the capsule is commanded to spin at a 6°-per-second rate until deceleration increases to 5g. At this point control ceases. With attitude reference control deleted, the blunt end of the capsule slowly turns into the flight path due to its aerodynamic static stability. The rate gyro control dampens any tendency to tumble, yet permits the capsule orientation to move as required to keep the heat-resistant blunt end leading. Pitch, roll and yaw attitude, as well as rate signals, are telemetered from takeoff to touchdown.



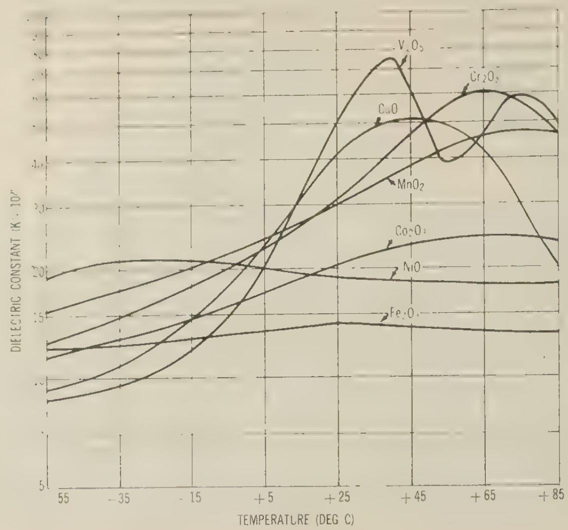
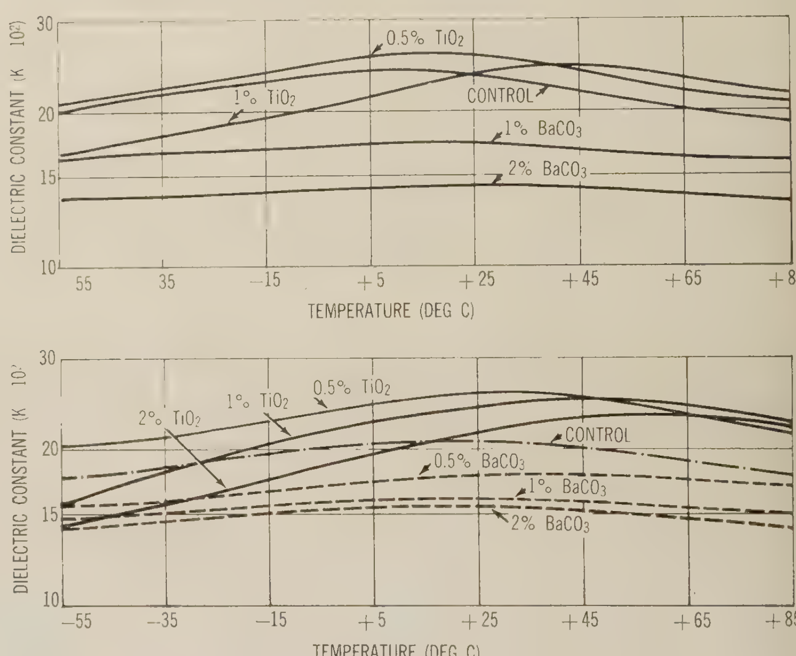


FIGURE 3: Effects of adding 0.5 per cent of various metallic oxides on the dielectric constant of a composition (by weight) of 95 per cent $BaTiO_3$ and five per cent $CaZrO_3$.



EFFECTS of adding baria and titania to metal oxide titanate compositions of 95 per cent $BaTiO_3$, five per cent $CaZrO_3$, 0.4 per cent Fe_2O_3, 0.4 per cent NiO (top, fired at 1415 deg C) and 95 per cent $BaTiO_3$, five per cent $CaZrO_3$, one per cent NiO (bottom, fired at 1375 deg C). Both compositions are by weight and were soaked one hour.

not significantly; they were also unsatisfactory because they produced high power factors.

Cobalt oxide improved the power factor and flattened the T-C curve, but the most advantageous materials by far were the nickel and iron oxides. These provide low power factors, high K, and stable T-C behavior.

As you might expect, the most critical variable of these addition processes is the metallic-oxide content. Iron and nickel oxides don't seem to be effective in quantities of less than 0.3 per cent. On the other hand, amounts of over two per cent (particularly in the case of Fe_2O_3) yield undesirably high power factors. Generally, metallic oxides apparently don't flatten the T-C curves appreciably if they are used in amounts of over two per cent.

Iron and nickel oxides differ slightly in their flattening actions. At a given oxide percentage, iron oxide generally produces lower K values but flatter T-C curves and nickel oxide generally produces lower power factors.

more on page 189

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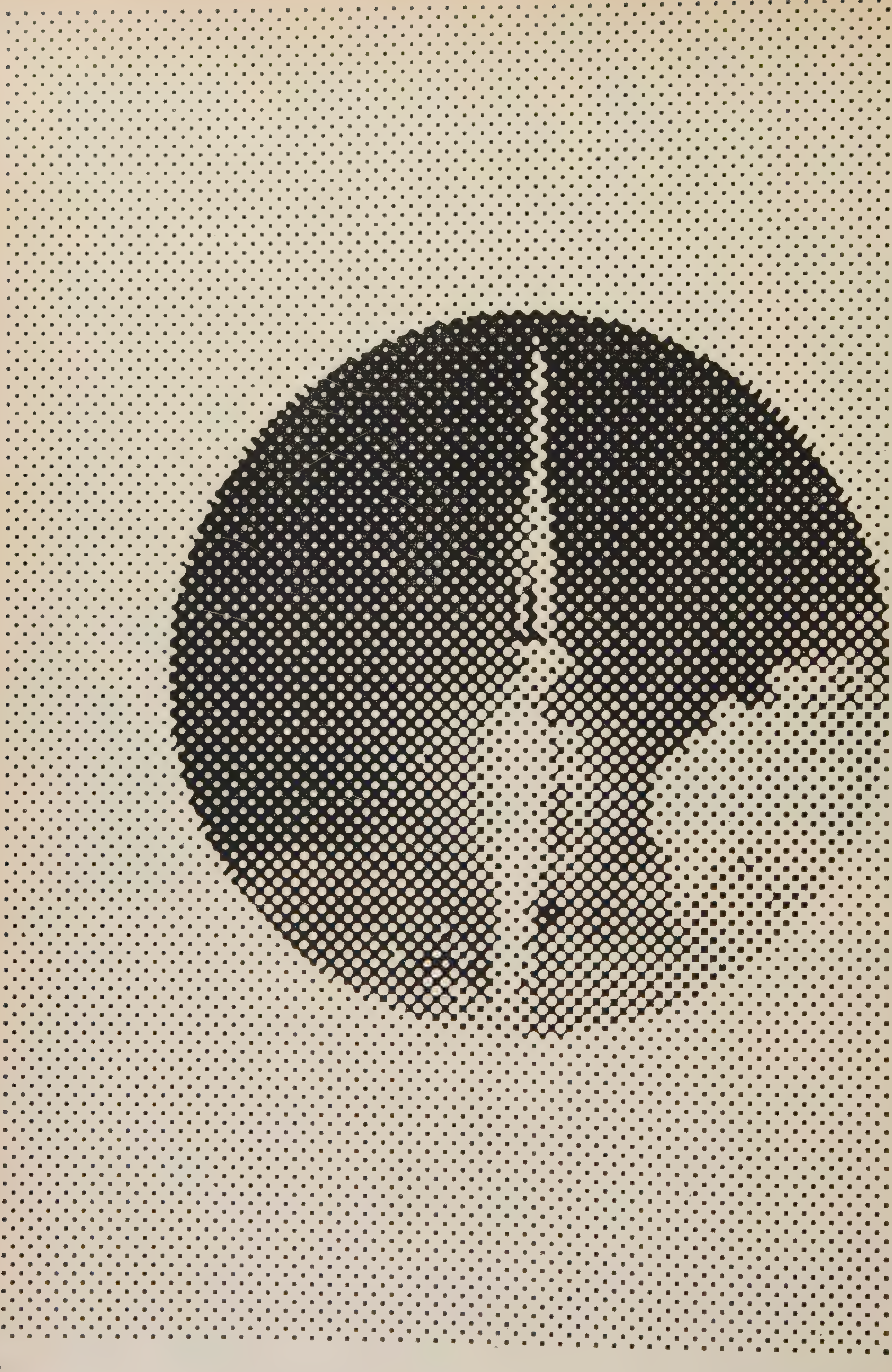


Two Typical High-K Materials

	A	B
Dielectric constant	6000	5000
Maximum decrease in capacity per cent (—55 to 85 deg C)	80%	70%
Composition (per-cent by weight)	80 $BaTiO_3$	89 $BaTiO_3$
	10 $SrTiO_3$	10 $CaZrO_3$
	10 $CaZrO_3$	1 $MgZro_3$

The sensitivity of the compound to metallic-oxide content emphasizes the importance of taking accurate weights of the oxide additions. Higher-K compounds with metallic-oxide additions of 0.3-0.7 per cent (K2500-4500) demand extremely accurate control of the titanate lot, the firing conditions, and the metallic-oxide content. In the lower K-ranges (K700-2200)—with 0.7-2 per cent metallic oxide—the requirements are less stringent.

Apparently, some volatilization occurs in the metallic oxide, as is indicated by stains on the firing plates. Metallic oxides, and nickel oxide in particular, greatly aid vitrification without producing a strong fluxing action. Dense, nonporous pieces therefore can be produced over a wide range of firing temperatures and intervals. A vitrification range of 75-100 deg C (corresponding to a 1325-1425-deg C firing temperature range) can be attained for some compounds, though 50 deg C is more common. Over this firing range, the dielectric constant progressively increases and the temperature curve becomes steeper.

Somewhat similar effects are obtained by lengthening the "soaking" period (the interval during which the material is at temperature). This procedure introduces additional variables, but their effect is offset by the three control parameters available with $BaTiO_3$-$CaZrO_3$ formulations. A deviation in one factor (say, oxide content), is easily compensated by changing one of the other factors.

The sintering control is sensitive enough so that dense disks with good electrical properties can be stacked in tiers in the furnace without sticking or interaction.—End

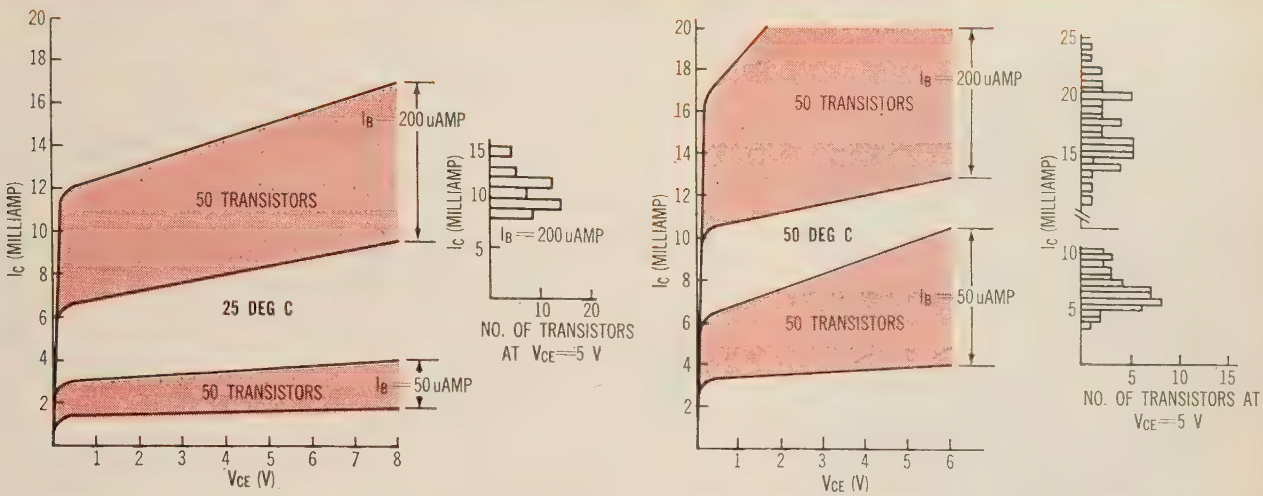


FIGURE 1: Spread of typical transistor characteristics (for 2N43A common-emitter units) at 25 and 50 deg C ambient. The distribution patterns to the left of the curves statistically relate the transistor performance to the circuit performance in a typical probability distribution.

Designing transistor circuits with statistical techniques

Designing transistorized equipment to military specs often is a frustrating job—mainly because of factors such as variability among units of a lot and spread of characteristics. Many of these problems can be overcome by the use of statistical design techniques.

by James R. McDermott, Consulting Engineer

MILITARY specs for transistors use the "absolute maximum" system of ratings: Rated values must not be exceeded under any specified condition of supply-voltage variation, change in ambient temperature, variation in resistors or other connected parts, equipment adjustment, or any combination of these conditions.

Although ratings are specified by single-values "min-max" limits, these are not absolute barriers, with continuing indefinitely satisfactory performance on one side and immediate degradation of performance on the other. Instead, the expected period of satisfactory operation decreases gradually as the rating is exceeded.

The numerical rating value usually is set to insure acceptable performance under the specified life-test conditions. These, however, are not necessarily closely related to field use. Specs for use under abnormal conditions, as during flight into upper radiation areas, may be lacking. In this case, other recent data, such as are given in the *Table*, can be used.

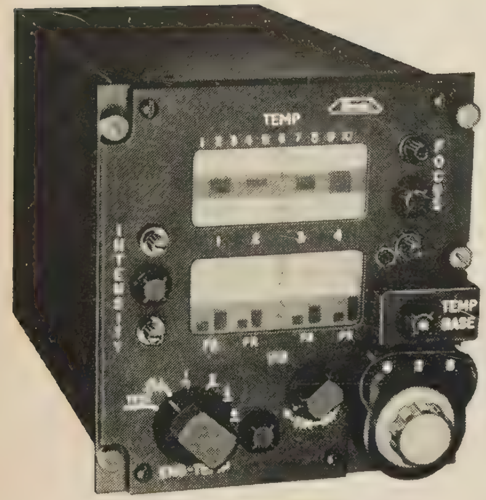
Important considerations are sometimes overlooked in the use of transistors in military equipment:

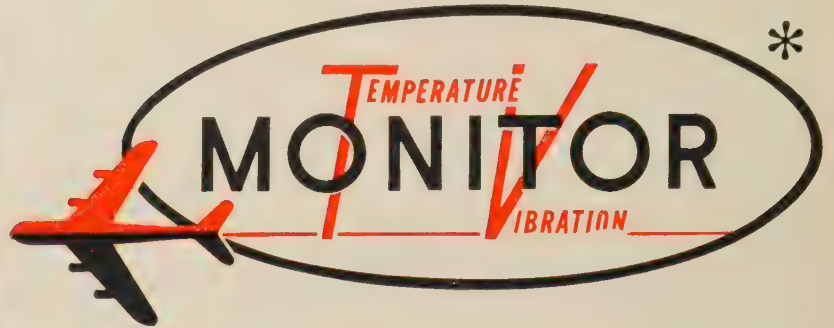
- Mil-STD-701 calls for equipment to be designed to meet per-

more on page 193

* This article is a condensation of parts of "Transistor Application Manual," prepared and published by Arinc Research Corp., 1700 K. St. N. W., Washington, D. C., from where copies of the Manual may be obtained at $1.50 each.

ANNOUNCING A NEW DEVELOPMENT BY BENDIX





FOR TURBINE ENGINES

Provides a continuous condensed display of turbine engine vibration and temperature conditions

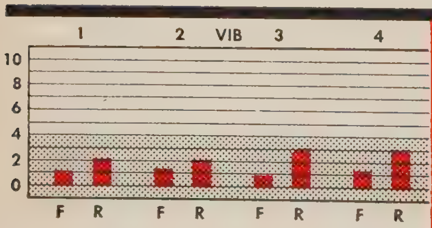
A landmark in engine instrumentation progress is the Bendix* Temperature-Vibration Monitor which simultaneously displays the findings of 40 temperature and 8 vibration sensors strategically located on all 4 engines of a turbine powered aircraft. This data is presented on the flight deck of the aircraft in bar graph form so that it can be continuously monitored and easily read.

The average displacement of 8 vibration pickups is displayed continuously on the lower cathode ray tube with the top of the bar graph indicating vibration displacement on the grid scale. This continuous monitoring of vibration immediately indicates excessive unbalance on the jet engine.

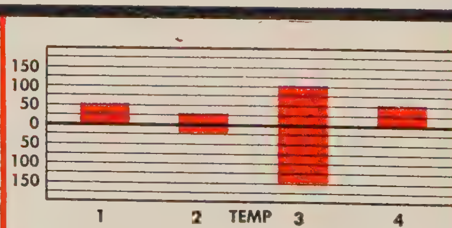
The temperature analysis normally associated with the exhaust gas thermocouples will locate faulty burners, bad combustion distribution and plugged nozzles or any unusual hot or cold conditions around the turbine engine exhaust. The temperature display in the "all" position presents maximum and minimum temperatures on the upper cathode ray tube continuously for the four engines as reference to a temperature datum set in by the operator. The individual engine temperatures can be displayed as 10 bar graphs whose deflection can be read on the tube scale as deflections above or below the temperature datum, and individual degrees may be accurately and easily read from the digital read-out dial.

The equipment, initially developed for BOAC, is applicable to all airline and military turbine powered aircraft. The equipment for the four engine installation is approximately 30 lbs. and includes the Temperature-Vibration Monitor pictured above and a remotely mounted ½ ATR short box.

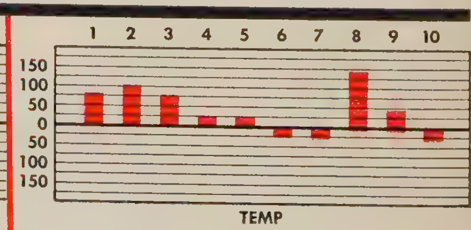
*TRADEMARK



Vibration indication for four engines with front and rear pickups on each. Height of display indicates total vibration displacement.



Temperature "all" display indicating maximum and minimum temperatures above and below temperature datum for four engines.



Temperature for single engine indicates all thermocouples indicating temperature above or below temperature datum reference.

Scintilla Division
SIDNEY, NEW YORK

Bendix
AVIATION CORPORATION

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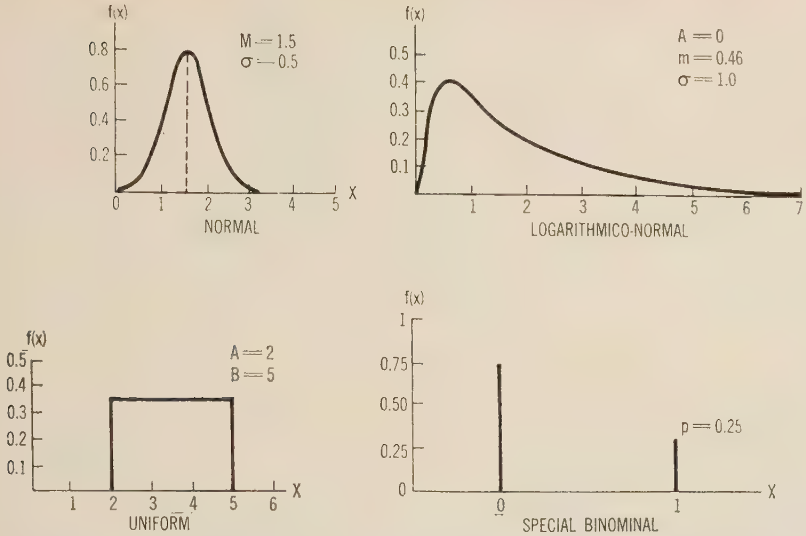


FIGURE 2: Probability distributions for three types of continuous distributions and an "attribute," or discrete, distribution (bottom right). In the discrete distribution, the units in the lot either have the attribute (line at $X = 1$) or do not have it (line at $X = 0$). The two curves at the top are product distribution curves.

formance requirements when stocked with transistors from lots whose electric characteristics are within spec limits and distributed in a typical manner.

- Installed transistors must not be replaced with other transistors of the same type to improve equipment performance unless those replaced do not meet the applicable military spec.
- Transistors should not be inspection-tested after receipt from the manufacturer, except to determine conformance of lot quality with military specs or to get circuit design information.

Transistor specs describe characteristics in terms of "attributes", or min-max limits, that cannot be used directly to find the spread of transistor characteristic variations. Nor can they be used to relate these variations to the expected variation in overall circuit output. However, statistical methods can be used to determine the distributions that transistor characteristics can take as related to transistor and part tolerances.

Circuit operation can be described in mathematical terms by assigning values to "essential" and "detrimental" transistor characteristics. Essential characteristics describe normal operation, such as base current, emiter current gain, and similar ratings. Examples of detrimental characteristics are collector cutoff current (I_{CO}) and noise factor (NF). Unlike the "essentials," they have no specified range of values; instead, they have a single specification limit on magnitude or frequency of occurrence.

Some "detrimentals" are present throughout the transistor's life; others show up as equipment breaks down because of aging. Both essential and detrimental characteristics must be evaluated on the basis of initial values and of the changes occurring with time.

When the transistors of a group are measured and sorted, the variations usually take the form of a probability distribution (*Fig. 1*). They may be sorted into items with values above or below a given value or into more groups than these two. As measurements and groups increase in number, the step-like pattern of distribution becomes smoother and more clearly defined.

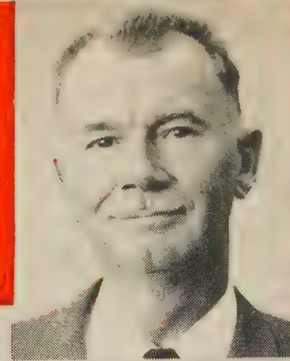
The pattern eventually approaches that of a theoretical continuous-probability distribution. Most of the time, the distribution approximates a normal curve; occasionally, an abnormal curve results. Whatever the shape of the distribution curve, the pattern will be well defined if the test conditions are approximately constant.

Figure 2 shows some of the

more on page 195

"Dependability is a Watchword at Lockheed"

JOHN B. WASSALL, DIRECTOR OF ENGINEERING, LOCKHEED AIRCRAFT CORPORATION



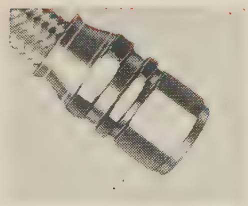
John B. Wassall, Director of Engineering, Lockheed California Division, is the chief executive of the huge engineering branch which employs 5700 people.

World's speed, altitude and time-to-climb champion, the sleek F-104 Starfighter, is an outstanding achievement in performance and dependability.

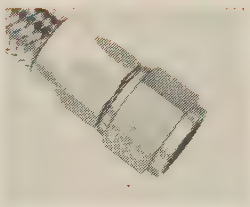
This spectacular new plane scorches the sky in 1500 m.p.h. bursts of speed. It climbs to the very fringe of earth's atmosphere in minutes!

Soundly designed, and utilizing the finest of quality products throughout vital systems, the F-104 is giving many hours of trouble-free service—thanks to Lockheed's devotion to dependability.

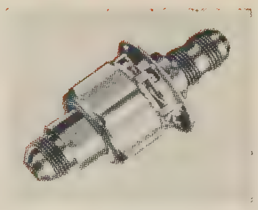
AEROQUIP PRODUCTS ARE USED BY LOCKHEED ON THE F-104



High performance 666 and 677 Hose of Teflon with patented* "super gem" Reusable Fittings for the hydraulic system.



Aeroquip 601 Hose Lines with "little gem" Reusable Fittings for the fuel system.



Quick-Disconnect, Self-Sealing Couplings for the hydraulic system.

Marman Clamps, Couplings and Joints used in many applications on the F-104.

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GERMANY

AEROQUIP G.m.b.H., Baden-Baden, Germany

JAPAN

THE YOKOHAMA RUBBER CO., LTD., Otemachi Bldg., 4, 1-chome, Otemachi, Chiyoda-ku, Tokyo, Japan

CANADA

AEROQUIP (CANADA) LTD., Toronto 19, Ontario

U.S.A.

AEROQUIP CORPORATION, Jackson, Michigan; Western Division, Burbank, Cal., Marman Division, Los Angeles, Cal.

*"super gem" and "little gem" are Aeroquip Trademarks. *U.S. Patent No's., 2,833,567 and 2,731,279*

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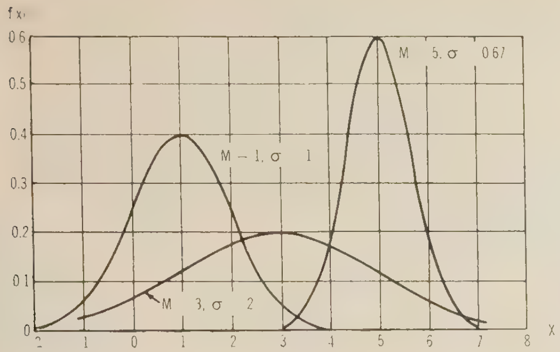

FIGURE 3: Normal distribution for three populations with different parameter values.

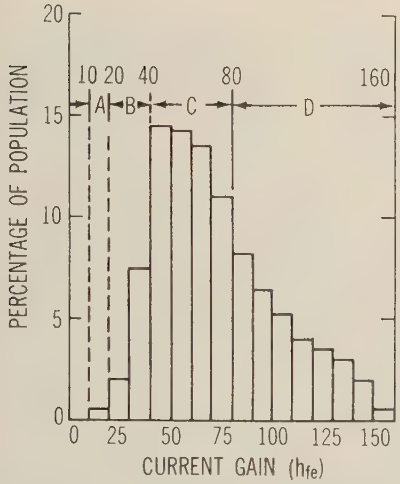

FIGURE 4: Production distributions of an NPN germanium transistor showing four spec limits based on a 2:1 h_{fe} ratio in each group (A, B, C, D).

forms that the probability distributions may take. The normal, logarithmico-normal, and uniform patterns are curves for continuously variable characteristics. The fourth pattern is that for a discrete variable, or an attribute that the units in the lot either have or do not have.

For example, current gain is a continuously variable characteristic and can have a wide range of values. However, it can also be considered as a discrete variable, for sorting transistors on a yes-or-no basis—transistors whose current gain falls within a prescribed range are considered good, those with current gains outside the range are considered defective.

Other properties of transistors intrinsically may be "attributes" since they either do, or do not, exist. For example, either there is or there is not a base connection. These attributes are measured in terms of probability of occurrence in a population, which is the total number in the group under statistical examination.

A population may be defined mathematically by the formula for its particular type of probability distribution. For example, the formula for the normal distribution shown in *Figure 2* is:

(1) $f(x) = 1/\sigma\sqrt{2\pi}e^{-(x-M)^2/2\sigma^2}$,

where $f(x)$ is the probability that all measurements will have the value x and M and σ are parameters or fixed constants of the population. For a normal distribution, M is the average of the expected value of the random variable x and indicates the location of the center of population. The standard deviation (σ) is a measure of the variation, or spread, of all the values throughout the entire distribution.

Different populations with the same type of distribution curve may have different parameter values. *Figure 3* shows normal distributions for such populations.

Statistical description of populations

A group of transistors identical in all respects would be completely described by the values for one transistor. Populations of interest in electronic circuit design must be described in terms of a type of distribution and of specific parameter values for that distribution. When the parameter values are known, the expected percentage of the population having values outside specified limits can be easily found by statistical methods.

In the inspection and testing a group of transistors—for acceptance or any other purpose—the population of interest may be the entire lot or a portion of the lot that is associated with a specific characteristic. When a lot is defined in terms of production units—

more on page 197


New Fafnir AW-AK Bearings
These new airframe control bearings are designed for low torque operation at temperatures in the 500° F range. The bearings are made of heat-stabilized 440C stainless steel, and equipped with Teflon fabric seals.
New Fafnir M-Series Bearings
Bearings in Fafnir's new M-Series—the first special precision series made for aircraft control systems—are held to closer tolerances to reduce play and backlash and increase sensitivity in power control systems.
New Fafnir GDSRP Bearings
This new series offers most capacity for weight and size. Dimensionally interchangeable with the DSRP series, GDSRP bearings are relubricatable, feature weight-saving balanced design, removable Plya-Seals, and self-alignment.

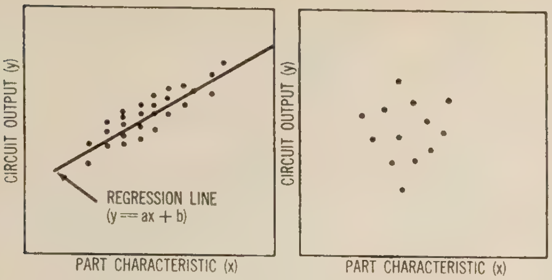

FIGURE 5: Application of statistical techniques in circuit design is shown by scatter plots with high correlation between part characteristic and circuit output (top) and with no such correlation (bottom).

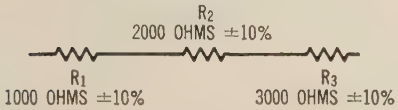

FIGURE 6: Series-type circuit to which statistical treatment of the sum (or difference) of part tolerances can be applied.

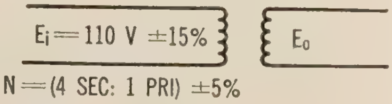

FIGURE 7: Type of circuit to which statistical treatment of the product (or quotient) of part tolerances can be applied.

e.g., 1000 transistors or a week's production—it is designated as a "production lot."

In acceptance testing, the variation of a single characteristic over a long production period can be plotted in terms of a "product distribution curve", which shows the variations in individual lots (*Fig. 2*).

Often, several types of transistors are selected from a production yield. For example, *Figure 4* shows how four types of transistors are chosen. The transistors are sorted so that the maximum current gain (h_{fe}) for each type is twice the minimum value.

Electronic-parts users often run special tests to select the parts with the highest probability of long life. Experience shows that such selectivity create more problems than it solves. It should therefore be carefuly evaluated in terms of its objective, effectiveness, and cost before it is accepted as standard practice.

When transistors or other parts are to be selected for narrow tolerances, you must determine the effect that possible drift of electrical properties with time would have on equipment performance and reliability. Whether or not spare parts selected to the same tolerances will be available for field maintenance is also important.

Where reliability selection tests are run, you should find out beforehand just how much reliability you need. Also, before you decide on 100 per cent inspection, check whether there isn't a cheaper lot-sampling plan that would also provide an acceptable level of confidence. Finally, consider the probability that added handling and other test-imposed stresses will aggravate incipient weaknesses in the transistors.

In transistor circuit design, the semiconductor characteristics must be considered in terms of both initial values and the change of values with time. This spread in performance of a simple circuit can be determined by computing it in terms of upper and lower limits of the transistor characteristics.

When the circuit becomes complex or the number of related characteristics increases, the probability that all characteristics have either all minimum or all maximum values is negligible. Under these circumstances, circuit performance can be related to transistor characteristics by statistical techniques.

The effect of part tolerances on circuit output can be found statistically, if the relationship between circuit function (y) and part characteristic (x) is known. If this relationship isn't known, it can be approximated by the statistical technique of linear regression.

Let us assume a circuit function (y) bears a linear relationship to a part characteristic (x). It is defined as:

$$(2) \qquad y = f(x) = ax + b.$$

The circuit output is measured when parts with known characteristics are connected. If enough randomly selected parts (x) are chosen—say, 30—the range of values x can have with the circuit output still remaining within toler-

more on next page

ance limits can be found from a scatter plot of this relationship. *Figure 5* shows two such plots, one with a high degree of correlation between x and y and one with no correlation.

When part tolerances are small compared with the nominal characteristic values and do not depend on one another (or interact) or when parts are randomly selected, the circuit characteristic values will be normally distributed. In this case, most circuits can be represented by an analytical expression relating circuit performance to part characteristics.

When the expression has the form:

(3) $y = f(x_1, x_2, \ldots, x_n)$,

where y is the circuit characteristic and x the part characteristic, a realistic set of limits within which circuit performance will lie can be obtained from:

(4) $\sigma_y^2 = (\partial y/\partial x_1)^2 \sigma x_1^2 + (\partial y/\partial x_2)^2 \sigma x_2^2 + \ldots + (\partial y/\partial x_n)^2 \sigma x_n^2$,

where σ is the standard deviation. The standard deviation of circuit performance is obtained by substituting nominal values of part characteristics in this equation.

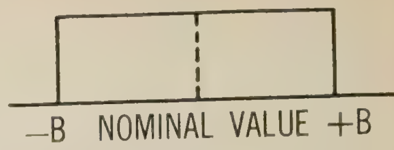

FIGURE 8: Rectangular distribution.

Statistical treatment of tolerances yields useful equations, for example, one defining the sum of tolerances:

(5) $y = x_1 + x_2 + \ldots + x_n$.

Computing the standard deviation of y by use of *Equation 4* we get:

(6) $\sigma_y^2 = \sigma_{x1}^2 + \sigma_{x2}^2 + \ldots + \sigma_{xn}^2$.

Tolerances of sums, as for the series circuit in *Figure 6*, can be combined if the tolerances (t) contain the same number of sigmas:

(7) $t_y = A\sigma_{y1}$, $t_{x1} = A\sigma_{x1}$, . ., $t_{xn} = A\sigma_{xn}$,

where A denotes the same number of sigmas. In this case:

(8) $t_y^2 = t_{x1}^2 + t_{x2}^2 + \ldots + t_{xn}^2$.

In the example shown in *Figure 6*, the resistor values are normally distributed and the tolerances are the limits of the three-sigma distribution. The sum of nominal resistance is:

(9) $R_t = R_1 + R_2 + R_3 = 3000 + 2000 + 1000 = 6000$ *ohms*,

and distribution of the sum is:

(10) $t_{Rt}^2 = t_{R1}^2 + tR_2^2 + t_{R3}^2 = 300^2 + 200^2 + 100^2$, $t_{Rt} = 374$ *ohms*.

The nominal value and the three-sigma distribution limits of this sum are: 6000 ohms ± 6.2 per cent. Note that, for series tolerances, the square root of the sum of the sum of the squares refers to actual distribution values and not to percentages of the nominal value. Tolerances of differences, or of sum and differences, can be similarly combined.

In certain types of circuits, like the transformer in *Figure 7*, the output is some multiple (or submultiple) of the input. The input voltage has a tolerance of ± 15 per cent. It is stepped up by a primary-to-secondary ratio of 4; the ratio tolerance is ± 5 per cent. Consequently, the tolerances for this circuit must be determined as the product (or quotient) of individual tolerances. In this case, the basic analytical expression is:

(11) $y = x_1 x_2 x_3 \ldots x_n$.

Applying the technique developed in *Equations 5 & 6*, we get:

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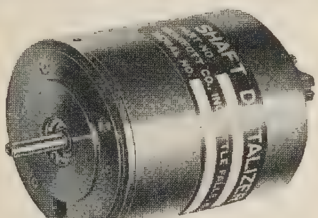
BASIC BUILDING BLOCKS FROM KEARFOTT



Analog-to-Digital Converters

Kearfott's rugged shaft position-to-digital converters are resistant to high shock and vibration and high and low temperature environments. Ideally suited for missile applications, these converters are available for many uses, including latitude, longitude, azimuth or conventional angular shaft displacement conversion and decimal count conversion. Exclusive drum design provides large conversion capacity in smallest size. Combination counter converter assemblies for both visual and electrical readout also available.

TYPICAL CHARACTERISTICS

Kearfott Unit No.	P1241-11A
Code	Cyclic Binary
Range	0-32,768 (2^{15})
Bits per Revolution	16
Revolutions for Total Range	2,048
Volts D.C.	10.5
Current (ma.)	20
Inertia (gm. cm.^{2})	20
Unit Diameter (in.)	1$\frac{7}{16}$
Unit Length (in.)	3
Life	10^6 Revolutions or 10^3 hours
Static Torque (in.-oz.)	2 (break) 1 (running)
Weight (oz.)	5
Maximum Speed (RPM)	600

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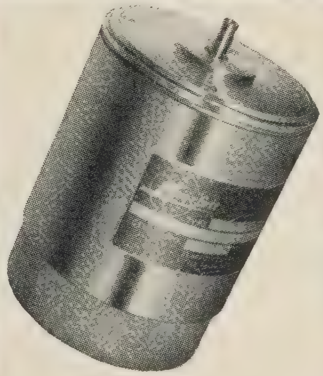
BASIC BUILDING BLOCKS FROM KEARFOTT



20 Second Synchro

This synchro, just one of a broad line offered by Kearfott, provides the extreme accuracy required in today's data transmission systems. Kearfott synchro resolvers enable system designers to achieve unusual accuracy without the need for 2-speed servos and elaborate electronics. By proper impedance matches, up to 64 resolver control transformers can also operate from one resolver transmitter.

TYPICAL CHARACTERISTICS **SIZE 25**

Type Resolver	Transmitter	Control Transformer
Part Number	Z5161-001	Z5151-003
Excit. Volts (Max.)	115	90
Frequency (cps)	400	400
Primary Imped.	400/80°	8500/80°
Secondary Imped.	260/80°	14000/80°
Transform. Ratio	.7826	1.278
Max. Error fr. E.Z.	20 seconds	20 seconds
Primary	Rotor	Stator

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BASIC BUILDING BLOCKS FROM KEARFOTT

Integrating Tachometers

Kearfott integrating tachometers, special types of rate generators, are almost invariably provided integrally coupled to a motor. They feature tachometer generators of high output-to-null ratio and are temperature stabilized or compensated for highest accuracy integration and rate computation. Linearity of these compact, lightweight tachometers ranges as low as .01% and is usually better than ± .1%.

TYPICAL CHARACTERISTICS

	Size 11 (R860)
Excitation Voltage (400 cps)	115
Volts at 0 rpm (RMS)	.020
Volts at 1000 rpm (RMS)	2.75
Phase shift at 3600 rpm	0°
Linearity at 0-3600 rpm	.07
Operating Temperature Range	−54° +125°

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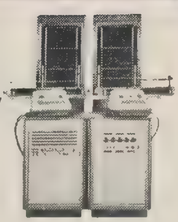
Miniature Floated Gyro

Electrohydraulic Servo Valve

Scanalog 200-Scan Alarm Logging System



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Engineers: Kearfott offers challenging opportunities in advanced component and system development.

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Susceptibility of Semiconductor Devices to Permanent Radiation Damage

Transistor Class	Integrated Neutron and Gamma Flux Causing Permanent Damage (NVT)
Thick Base	
Silicon	5×10^{10}—10^{12}
Germanium	10^{11}—5×10^{12}
Medium Base	
Silicon	10^{11}—5×10^{12}
Germanium	5×10^{11}—10^{13}
Thin Base	
Silicon	10^{12}—2×10^{13}
Germanium	10^{13}—5×10^{14}

(12) $\sigma_y^2=(x_2x_3 \dots x_n)^2\sigma_{x1}^2+(x_1x_3 \dots x_n)^2\sigma_{x2}^2+ \dots +(x_1x_2 \dots x_{n-1})^2\sigma_{xn}^2.$

Dividing this expression by y gives:

(13) $(\sigma_y/y)^2=(\sigma_{x1}/x_1)^2+(\sigma_{x2}/x_2+ \dots +(\sigma_{xn}/x_n)^2.$

Tolerances of products (T) can be combined directly if they contain the same number of sigmas and are expressed as percentages. If:

(14) $T_y=A(\sigma_y/y)100,\ T_{x1}=A(\sigma_{x1}/x_1)100, \dots, T_{xn}=A(\sigma_{xn}/x_n)100,$

a basic equation for products can be written as:

(15) $T_y^2=T_{x1}^2+T_{x2}^2+ \dots +T_{xn}^2.$

For products, the square root of the sum of the squares refers to tolerances expressed as percentages rather than as actual values.

For the circuit in *Figure 7* nominal output voltage is:

(16) $E_o=NE_i=4\times110=440$ V.

The distribution of voltage may be expressed as:

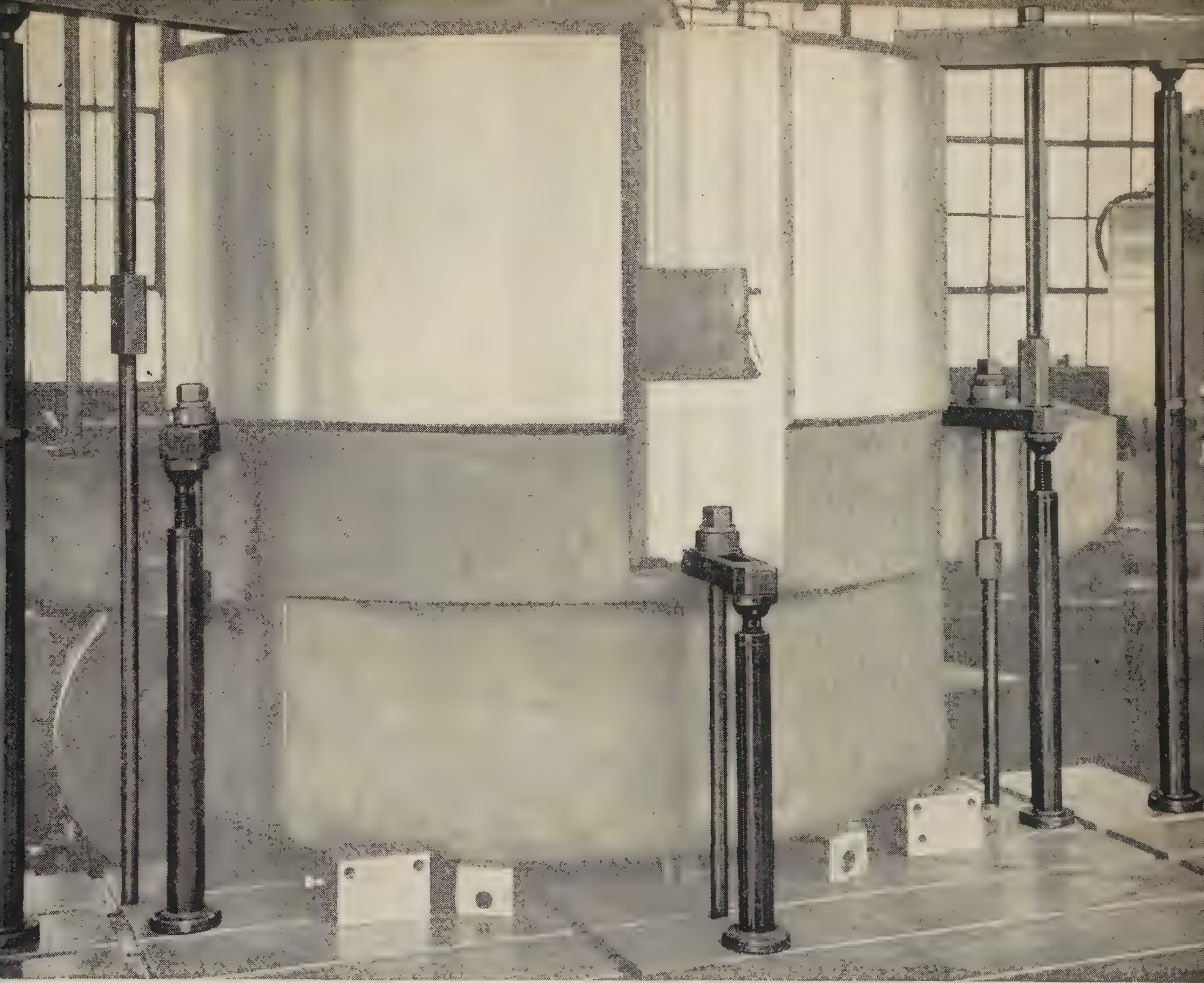
(17) $T_{Eo}^2=T_N^2+T_{Ei}^2=5^2+15^2,$ $T_{Eo}=15.8$ *per cent.*

The limits on output voltage are 440±15.8 per cent, or 440±69.5V.

When a special parts selection is made, as on the basis of narrow tolerance limits from a production group with wide limits, the values of parts characteristics will not be normally distributed. Statistical techniques for analyzing distributions that deviate somewhat from the normal are relatively complex. However, when the distribution is rectangular (*Fig. 8*), the standard deviation of the part value to be used in the general expression for determining the standard deviation of circuit characteristics should be computed from:

(18) $\sigma=B/\sqrt{3},$

where B is the limit shown in *Figure 8*.—End



Here's how Handy Clamp and Jack Set clamps down on machining costs . . .

JACKS UP PRODUCT PERFORMANCE

USS National Seamless Mechanical Tubing helps one of our customers* do both. By using Mechanical Tubing in their clamp and jack sets, our customer finds it unnecessary to machine the ID before threading the ends; that painting requires no special preparation, and that, compared to bar stock, tubing is lighter to handle and ship. Three different sizes of sets are offered: 1″ diameter, 1½″ diameter and 1¾″ diameter, all with 5/32-inch wall.

USS National Seamless Tubing helps cut processing costs because it eliminates drilling operations. It enables you to replace drills with simple, less expensive boring tools. And, it reduces tool wear and tool changes.

USS National Seamless Tubing gives you a superior cross section for a part that is designed to withstand equal loading in any direction. It resists bending stresses. It absorbs and localizes shock. And in torsion, it provides a better material distribution, and for a given weight, can withstand more load than other sections.

There's a National Tube Distributor located near you. He's expertly trained in solving all types of tubing problems. So, if you'd like to learn how USS National Seamless Steel Mechanical Tubing can be applied to your designs, see him . . . soon!

USS and National are registered trademarks

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The world's largest and most experienced manufacturer of tubular products

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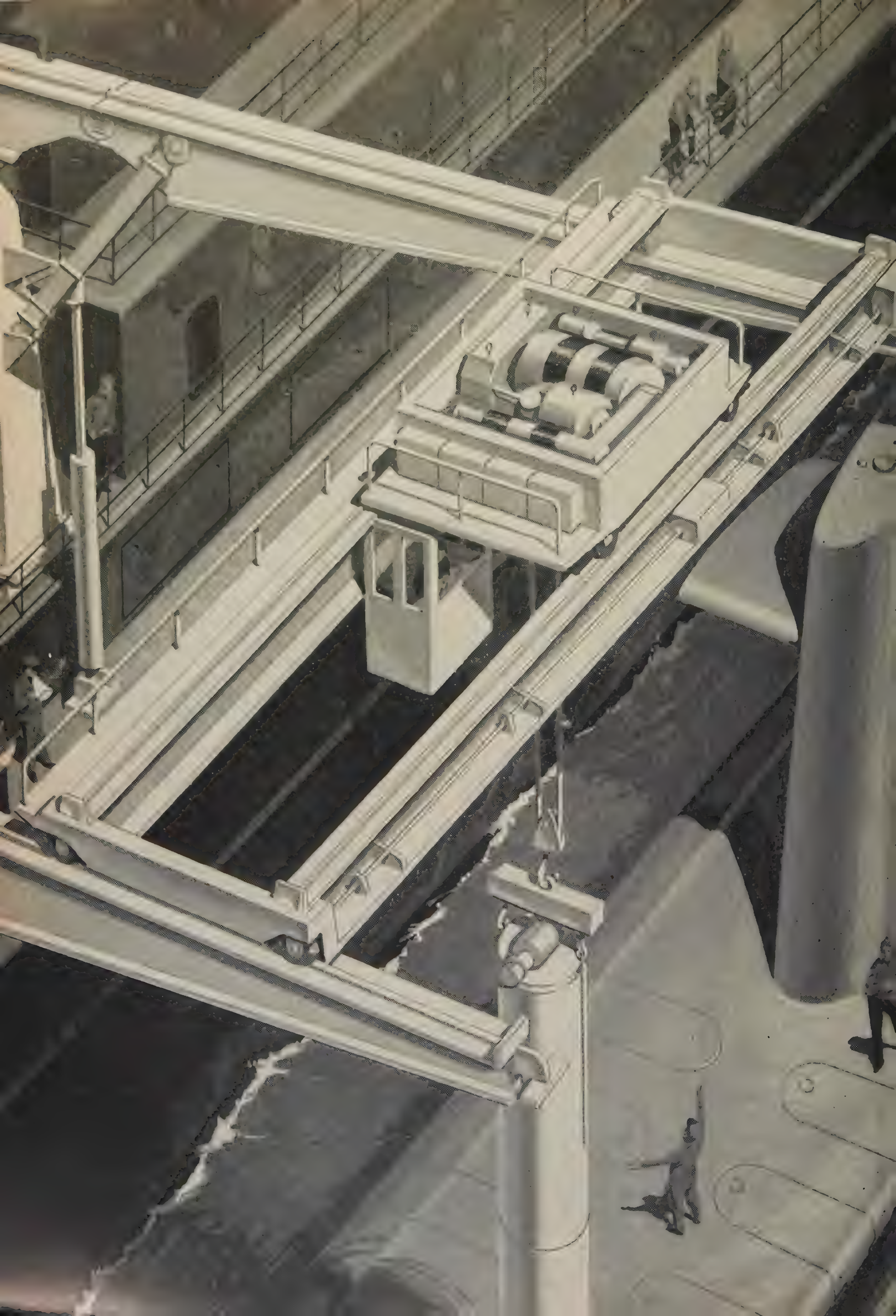

Threading the needle with a POLARIS missile using Westinghouse Load-O-Matic controls

Easing POLARIS missiles from a tender into the launching silo of an atomic submarine takes a handling system that combines ruggedness with extreme maneuverability and safe, sure, precision control—control so sensitive that the POLARIS seems to float in the air as it swings smoothly and gently into position in the submarine.

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Whatever your requirements for missile handling equipment—drive systems for launchers, erectors, shelters, loaders, or shockproof equipment for hardened sites—take advantage of the Westinghouse engineering knowledge, experience, range of products and unit responsibility for any type of electromechanical system. Contact your Westinghouse sales engineer or write: Westinghouse Electric Corporation, 3 Gateway Center, Pittsburgh 30, Pa.

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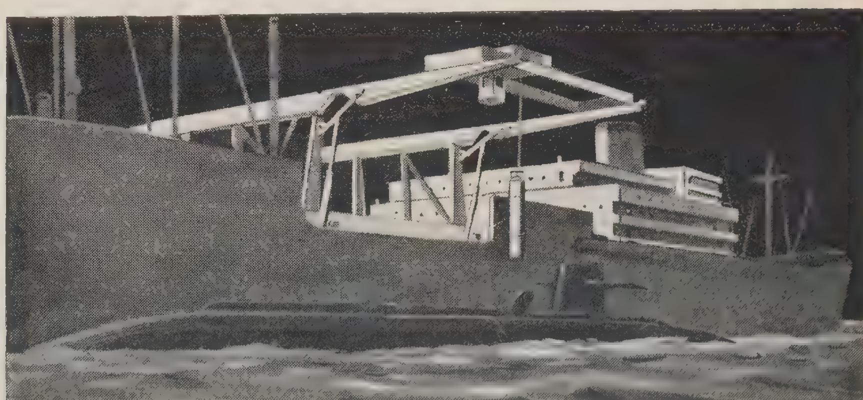

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[1]Located at Sedro Wooley, Washington.

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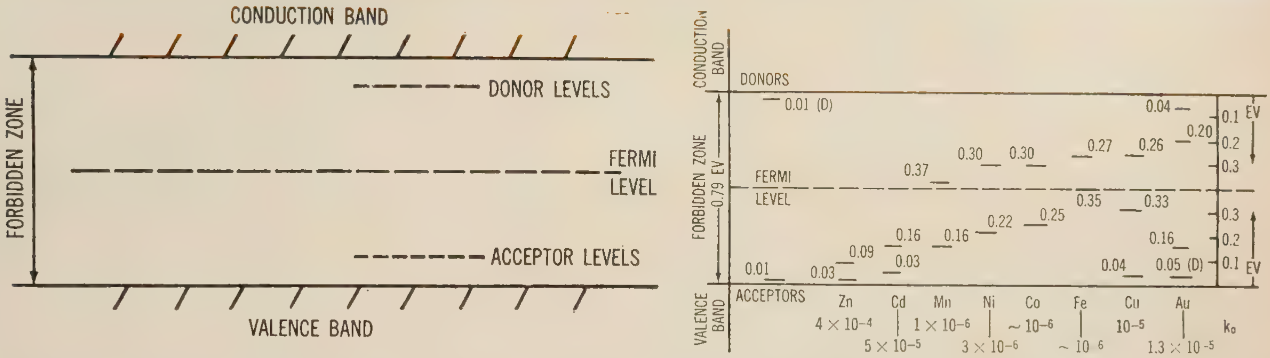

FIGURE 1: Electronic energy structure (left) of semiconductors. Right: Impurity levels in germanium, as measured at absolute zero temperature. ("D" identifies donors.)

Photon IR detectors:

physics and applications

Infrared detector design has progressed so far recently that a review of the basic physics of the latest devices seems in order. Here is a brief survey of the essential characteristics and applications of the three types of photon detectors used most frequently in IR systems.

by Marvin M. Antonoff, Design Engineer,
Light Military Electronics Dept., General Electric Co.*

DURING World War II, scientists on both sides put much effort into developing sensitive, fast-responding detectors to replace thermal detectors in infrared (IR) systems. This led to the development of photoconductive lead-sulfide IR detectors by German and American scientists. Today, photoconductive detectors are used almost exclusively in IR systems.

The photoconductive detector is one of several types of so-called "photon detectors". Unlike the thermal detector, the photon device doesn't depend on a change in its temperature. Instead, photons making up the incident radiant energy interact with matter to produce changes in one or more properties of this matter. Photon detectors are used in systems that demand fast response, thermal detectors in systems that demand broad spectral response.

The photon detector bears its name because its response is proportional to the particular number of photons—rather than to the energy—absorbed by the receiver. Photon detectors applied to the detection of IR radiation can be photoemissive, photoconductive, or photovoltaic. In all cases, the optical excitation of an electron results from the absorption of a photon of energy:

$$E = hc/\lambda,$$

where h is Planck's constant; c, velocity of light; and λ, wavelength of the incident radiation.

In the photoemissive detector or photocell, an absorbed photon with an energy greater than the work function (ϕ) of the material can release an electron from the material (producing the well-known photoelectric effect). Detectors of this type are limited in their response by the work function of the photocathode. Though a photon of visible radiation may have enough energy to release electrons, the photons become less energetic as you approach the longer wavelengths. Ultimately, they fall below the min-

more on page 208

* Light Military Electronics Dept., General Electric Co., French Rd., Utica, New York.

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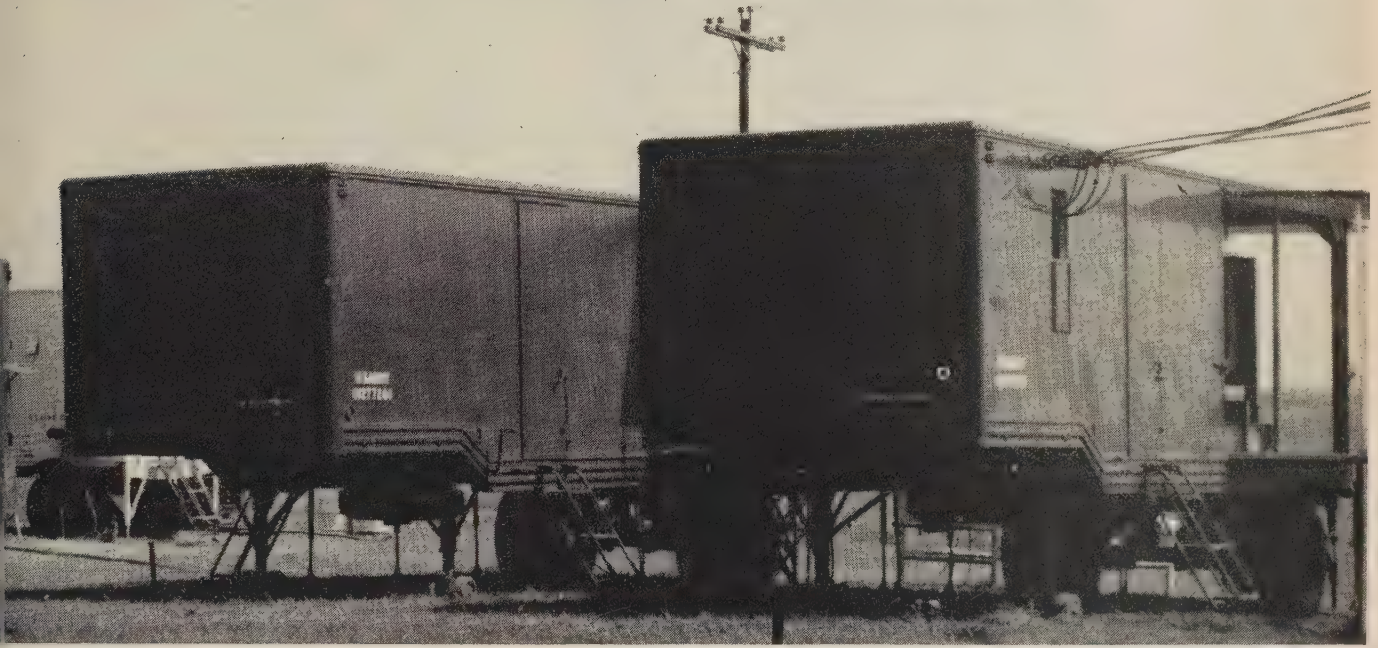

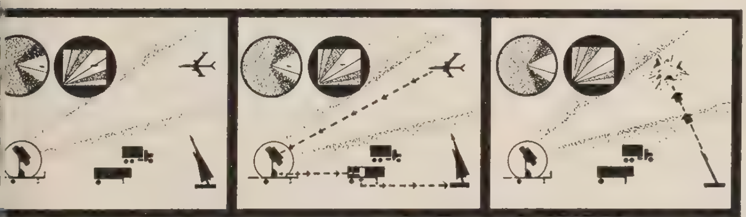

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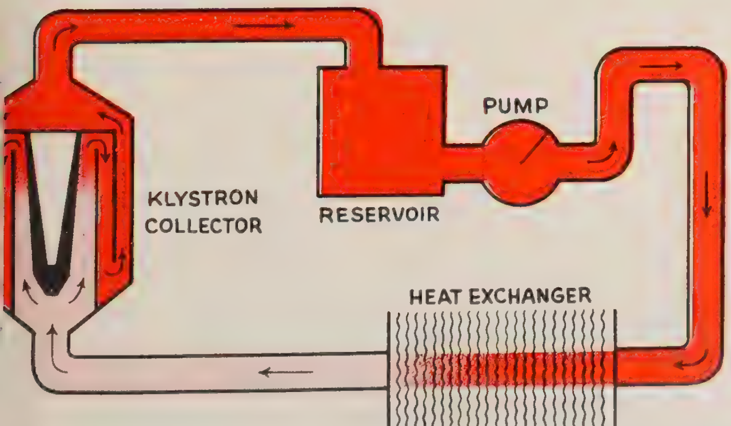

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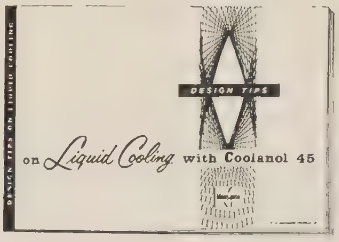

Gives useful information about static and dynamic cooling methods, how to apply the package concept to cooling design, how to simplify and standardize cooling and hydraulic units. Through a step-by-step solution to a typical klystron cooling problem, it shows you how to apply principles of heat transfer in actual practice. For your copy, circle the reader-service number or write:

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imum energy required to overcome ϕ. No further electrons can then be emitted from the surface.

The work function thus sets the long-wavelength limit of the detector's spectral response. Photoelectric emission has been observed in response to one-micron radiation; however, this seems to be the long-wavelength limit.

Though radiation beyond one micron hasn't enough energy per photon to produce photoelectric emission, it may excite normally bound electrons into states in which they are free to move in an electric field. This process of "photoconduction" consists of:

- the production of charge carriers (electrons and/or holes) by incident radiation;
- the motion of the carriers under the influence of an electric field;
- the return of the carriers to the bound state.

To understand how carriers are generated we must be familiar with the electronic energy levels of semiconductors and insulators. In the isolated atom, electrons are found at discrete energy levels, and the energy is said to be quantized. As atoms are brought together to form a crystal, the potential at the *n*th atom is changed by the proximity of the others. The result is that the free-atom energy levels are split into bands of energy levels.

The number of levels within each band is related to the number of atoms forming the crystal. Macroscopic crystals have so many atoms that the number of levels within each band may be considered to be infinite and the possible energy levels to be continuous within each band.

The valence levels of the atoms produce valence bands. In semiconductors and insulators, the largest energy level within the valence band is separated from the excitation levels in the conduction band by a region in which no electronic energy states exist. This is the so-called "forbidden zone." Actually, imperfections of the crystal and impurities in the crystal lattice can produce electronic energy states in the forbidden zones, and real crystals do have some energy levels within this region (*Fig. 1*).

Charges can be transported through the crystal by either or both of the following methods:

- by accelerating electrons in the conduction band through the in-

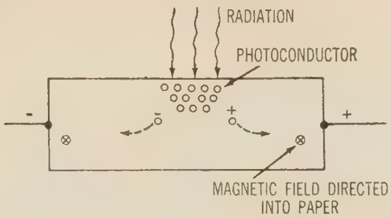

FIGURE 2: The photoelectric-magnetic (PEM) effect. The open little circles indicate photo-generated carriers.

fluence of an external field,

- by positively charging holes in the valence band that are analogous to electrons in the conduction band.

The generation of charge carriers depends on the excitation of the electrons into higher energy states. There are two distinct types of electron excitation:

- *Intrinsic excitation,* as when an electron in the valence band jumps to a level in the conduction band—Such transitions do not involve any states in the forbidden zone. An intrinsic excitation results in an electron in the conduction band and a hole in the valence band.
- *Impurity excitation,* involving energy states in the forbidden zone —An electron can, for instance, be excited from a level in the forbidden zone to the conduction band, producing an electronic carrier. The state in the forbidden zone is then termed a "donor." "Acceptor" states in the same zone can accept electrons from the valence band. Transitions of this type produce holes in the valence band and so result in hole conduction.

An important feature of electronic excitation is that any transition between levels can take place only if an electron receives an amount of energy equal to the energy difference between the excited and unexcited states. The required energy can come from the thermally excited lattice or from radiation incident upon the crystal.

If the energy difference between the final and initial levels is:

$\Delta E = E_f - E_i$ *electron-volts,*

the wavelength of an incident photon can be determined from $\Delta E = hc/\lambda$ and:

$\lambda = hc/\Delta E = 1.24/\Delta E$ *microns.*

Radiation of a wavelength longer than $1.24/\Delta E$ can't cause the same transitions between E_f and E_i as the shorter wavelengths.

For detecting IR radiation beyond 10 microns through a photoconductive device, it's clear that energy differences on the order of 0.1 electron-volt (ev) or less are needed. *(Fig. 1).* shows some of the measured energy levels introduced into the forbidden zone of germanium by several impurity atoms. Zinc, for instance, produces two levels—0.03 and 0.09 ev—that could be used to detect radiation at wavelengths beyond 13 microns.

In contrast to photoemissive and photoconductive detectors, the photovoltaic cell needs no external power source. Instead, it generates a voltage that constitutes the signal. Two types of photovoltaic cells have been used: the PN junction cell and the metal-semiconductor contact. Familiar examples of the latter are the selenium and cuprous-oxide cells.

Indium antimonide junction was key development

The PN junction photovoltaic detector recently gained prominence through the development of indium antimonide junctions. According to Moss, it can best be understood if you consider a semiconductor material that is N-type at one end and P-type at the other.[1] Let's further assume that there is a sharp transition between the two regions—the PN junction. In equilibrium, a potential exists across the junction, so that there is no net current.

When the junction is illuminated, new carriers are generated whose recombination rates do not have to be and usually aren't equal. The operation of the PN junction depends primarily on the variation in density of the minority carriers in both P- and N-regions. The unbalanced carrier distribution produces a current flow across the junctions until equilibrium is once again attained. The resulting photovoltage may be expressed as:

$$V = kT/e \log (l + Q/A),$$

where k is Boltzman's constant; T, absolute temperature; Q, rate of carrier-generation due to illumination; e, electronic charge; and A, rate of carrier generation due to thermal excitation.

The photovoltage is independent of detector geometry if the junction area is large and the transition region thin. The spectral response and

(1) T. S. Moss, "Photoconductivity of the Elements;" Butterworths Scientific, '52.

more on next page

the time constants of the photovoltaic and photoconductive detectors are basically the same, since they depend on the same processes of carrier generation and recombination.

The photoelectric-magnetic (PEM) effect enables us to measure carrier production in an intrinsic photoconductor. When appropriate radiation is incident on the detector, it's strongly absorbed near the surface, producing hole-electron pairs. The carriers thus produced diffuse into the crystal at some average velocity and in a direction normal to the surface.

When a magnetic field is applied transversely to the diffusion velocity of the carriers, electrons are deflected in one direction and holes in the other. (This phenomenon is similar to the deflection of carriers in the Hall effect. The carriers are separated according to the sign of the charge. A potential difference corresponding to a Hall voltage occurs across the detector *(Fig. 2)*.

The spectral response and time constant of the PEM detector are about the same as those measured photoconductively in the intrinsic region of the response. You might expect this, since both processes are governed by the same mechanisms of carrier production.

Most recent advances in IR masers

The most recent advances in IR detection and amplification have been made through the study of IR masers. In maser operation, an unstable gathering of atomic or molecular systems is introduced into a cavity whose resonant mode is normally near the frequency corresponding to radiative transitions of the systems. When you allow radiation to enter the cavity, it stimulates the decay of the unstable systems toward the stable condition. The result is "stimulated emission" of radiation. The energy emitted by the maser is usually extremely monochromatic, since the energy produced by stimulated emission is much greater than that due to spontaneous emission.

The maser has proven capable of high sensitivity in detecting and amplifying microwave and RF energy. To operate it in the IR region, however, you must make some modifications. To keep a single isolated mode in a cavity at IR frequencies, the cavity dimensions would have to be on the order of one wavelength —about 10^{-3} cm. A cavity of this size being impractical, studies have been made of larger cavities that may support a large number of modes within the desired frequency range.

Schawalow and Townes have investigated the operation of an IR maser using a one-cm^3 cavity.[2] They conclude that a cavity of this size can be developed into an IR maser. Though the IR sensitivity of such a maser couldn't compare with the performance of the photon devices we discussed earlier, its exceptional amplification properties should make the maser suitable for certain special applications.—End

FURTHER REFERENCES — A. Sommers, "Photoelectric Tubes;" Methuen, '46. A. Rose, "Photoconductivity Conference;" Wiley, '54. F. Seitz, "Modern Theory of Solids;" McGraw-Hill '40. L. P. Hunter, "Handbook of Semiconductor Electronics;" McGraw-Hill, '56.

(2) A. L. Schawalow & C. H. Townes, *Physics Rev.* 112/1940 ('58).

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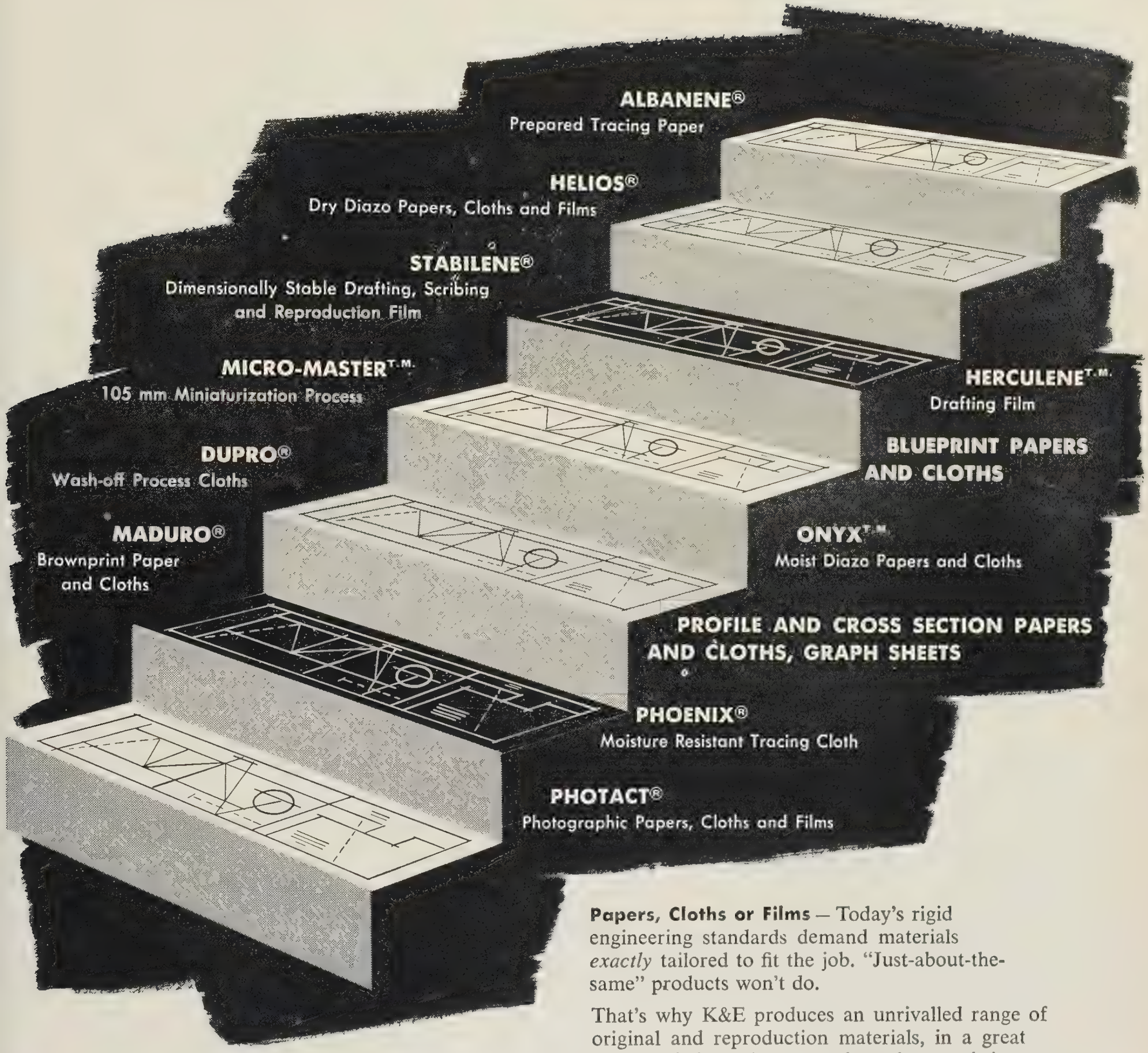

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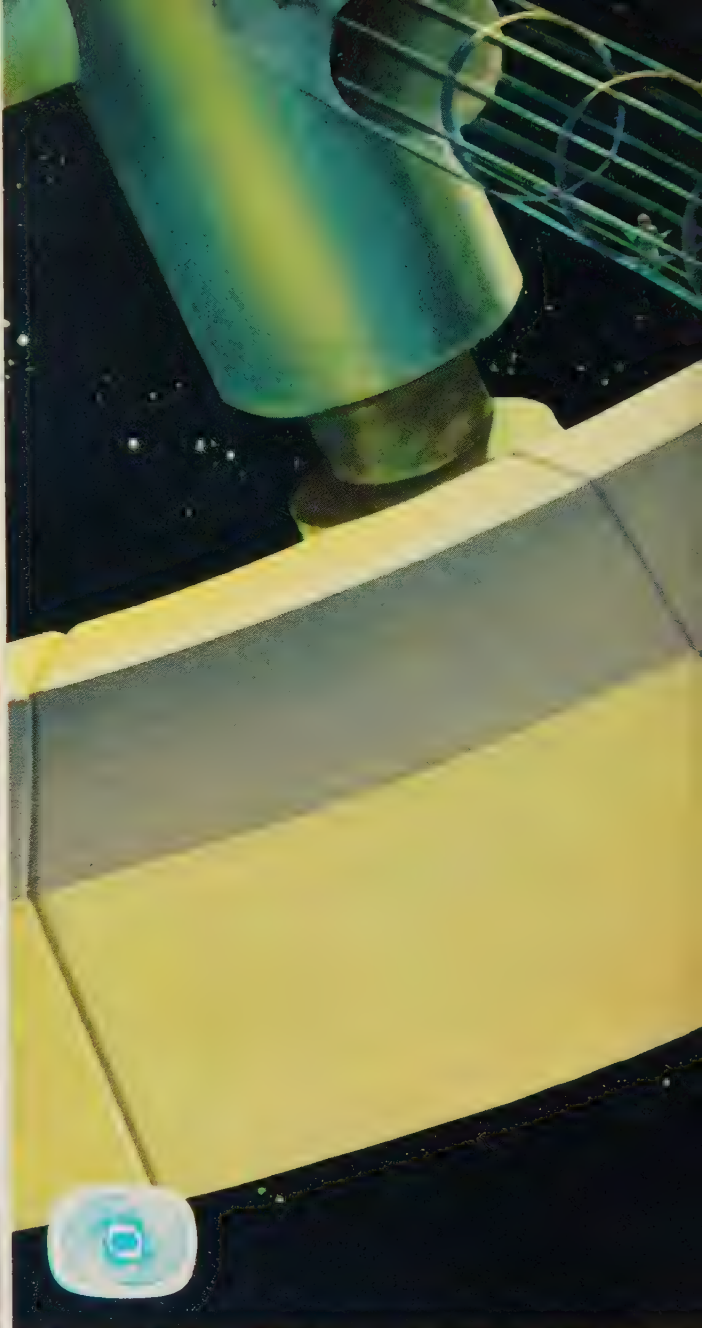

This is our R. L. Lillestrand, Project Engineer. Here he examines a model of his Stellar Aberrascope, a multiple star tracking device which is expected to provide the measurement of space vehicle velocities to accuracies of the order of 100 feet per second. The Aberrascope is designed so that precise alignment of the star trackers is not necessary. His investigations could have a bearing on self-contained guidance systems used in future space vehicles.

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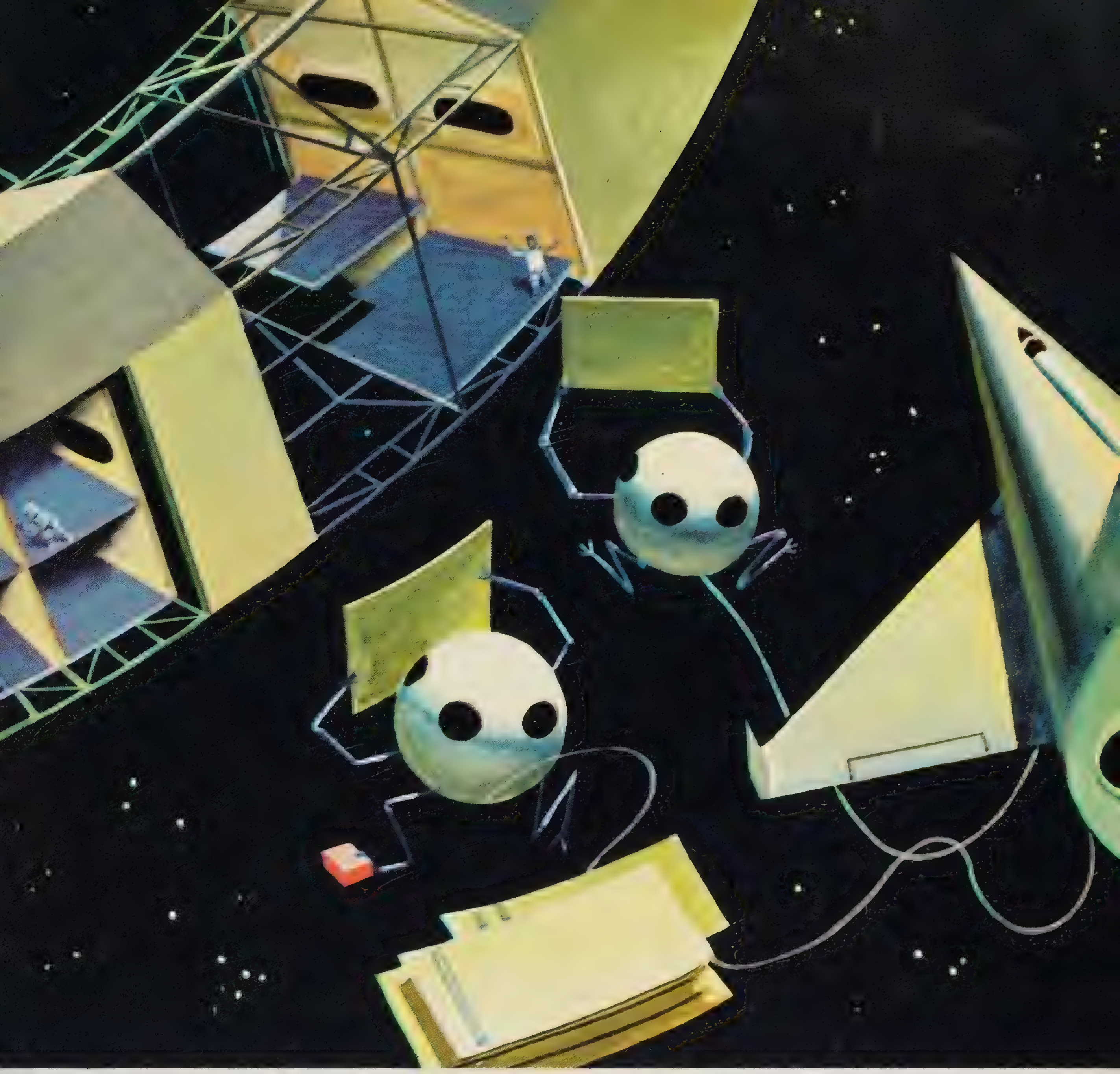

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INSULATION research at Bell Labs has uncovered a way of forming fluoride coatings on copper, aluminum, and other wire metals that provide excellent insulation at temperatures approaching the melting point of the conductor itself. Even at these high temperatures, the insulation is said to retain flexibility and freedom from porosity.

The insulating coatings are formed directly on freshly cleaned copper or aluminum exposed to the oxidizing carriers of hydrogen fluoride or elemental fluorine at 300-600 deg C. The thickness of the resulting film depends on the forming temperature, the concentration of fluorine, and the exposure time. Aluminum forms a fluoride film that becomes one micron thick in a few moments at 550 deg C. The film sticks to the wire even when bent repeatedly at a 90-deg angle.

ACCORDING to Bell Labs, the electric insulation values for copper and aluminum films 1-2 microns thick are on the order of 10^{10} and 10^{11} ohms at room temperature. The aluminum fluoride insulation resists breakdown at 450 V at 500 deg C. (The best organic insulation coatings can't be used continuously above 300 deg C.)

ELECTRON tubes may one day be "transistorized" if a recently discovered means of obtaining steady electron emission from certain semiconductors can be applied practically, Westinghouse researchers say. The latest material to yield this electron emission is silicon carbide. According to Westinghouse, the density of the emission is equal to that in the average tube.

"Applied successfully to a vacuum tube, this new method of electron emission would do away with the whole inefficient process [of boiling electrons out of the cathode at high temperatures]," declares Dr. Clarence Zener, director of Westinghouse research. He foresees a "solid-state" electron tube in which the conventional heated cathode is replaced by a small "semiconductor crystal with a built-in junction," as in a transistor. A small voltage maintained across this crystal would produce an instantaneous and continuous electron flow.

TEXTOLITE, a new transparent laminate developed by GE's Laminated Products Dept., is said to have ideal characteristics for computer circuitry and other military electronics applications. The new NEMA grade 11 laminate, self-extinguishing epoxy glass has 20-million meg resistance at 50 deg C and 500,000 meg resistance at 165 deg C. It reportedly retains 65 per cent of its RT flexural strength at 150 deg C.

APPLICATION of ferromagnetics as storage devices is being studied at Laboratory for Electronics. The company is investigating the micromagnetic properties of vacuum-evaporated thin films and the effect of controllable characteristics on these properties. The study—backed by ANIP through Bell Helicopter, ONR, and USAF's Cambridge (Mass.) Research Center as well as by LFE itself—is aimed at establishing a new class of storage and display devices whose operation is based on the detailed properties and motion characteristics of domain walls.

A NEW polycrystalline optical material with high infrared transmission qualities was developed by Eastman Kodak for use in low cost missile irdomes. Polished domes and windows of "Irtran" have improved heat resistance and weathering properties and generally cost less than their conventional sapphire and silicon counterparts, says Kodak. In structurally adequate thicknesses, Irtran reportedly transmits more than 90 per cent of the impinging energy from three to six microns.

Company tests show the high transparency is retained at 800 deg C and even beyond, so that it easily overcomes the "hot window" effect. The refraction index at 6.7 microns is only 1.301. Refraction losses therefore are small enough to make coating unnecessary, Kodak believes. Irtran's microwave characteristics for insertion losses and reflection in the 9-10-kc range are close to those of natural mica, Kodak adds.

WIDER use of copper-clad plastic laminates for printed circuits is predicted by Formica. The company foresees an increase of 500 per cent by '61 over '57, in view of the growing mass production of military electronic equipment. Copper-clads accounted for 4.4 per cent of all printed circuits in military electronics in '57 and should jump to 28.2 per cent in 1961, if Formica is right.

TRANSISTORS and diodes that operate at about 1800 deg F may result from development work at Stanford Research Institute. Working with silicon carbide crystals grown from solution in alloy salts—a method originally proposed by Nobel laureate William Shockley—SRI researchers have come up with a practical production method. In a modified standard crystal-pulling furnace, they melt pure silicon in a carbon receptacle. The carbon of the crucible diffuses into the molten silicon and saturates the solution. By close temperature control, a "cool spot" is produced in one area of the solution from which pure silicon carbide crystals can be grown.

The trick, SRI told SPACE/AERONAUTICS, lies in producing single crystals with the necessary extreme purity. At present, the SRI-grown crystals are too small for commercial uses. However, work is proceeding under a contract extension from BuShips to produce larger crystals.

RESEARCH on high efficiency thermoelectric material is underway at Servomechanisms' Santa Barbara (Calif.) Research Center under the ANIP program. Its aims are finding materials that have a relatively high conversion efficiency as well as devices that could use these materials. Thermoelectric properties that are retained at extremely high temperatures is a basic goal of the materials research program.

Much of Servomechanisms' effort is devoted to the mechanical problems in designing a thermoelectric generator, which has been a big obstacle.

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- ☐ Bell Aircraft Corp. — 229, 324
- ☐ Chance Vought Aircraft, Inc. — 248
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OTHER (Some organizations' recruitment advertising in this issue may have arrived too late for inclusion in the above list. If you are interested in the employment offers of any of these organizations, just note its name and the page number of its advertisement in this space. Please refer only to ads keyed to this form.) :__________

NOTE: If you have an immediate interest in any special employment opportunity advertised in this issue and would like to give more details about your qualifications than can be noted on this Form, we advise you to send your resume directly to the person or department given in the advertisement. We'd appreciate it if you'd mention SPACE/AERONAUTICS in your application.

space/aeronautics

CONFIDENTIAL

November 1959
(good until 1/15/60)

Employment Inquiry Form

Please type or print (with pencil)

(NOT an application for employment)

FIELDS OF INTEREST (in order of importance, note the general fields in which you would like to work—e.g., basic research, dynamics, structures, rocket propulsion, electronic systems, pneumatics, testing, materials, production, ground support, etc.): ______________________

SPECIALIZED JOB EXPERIENCE (describe the specific technical areas in which you have worked—e.g., flutter, fatigue, fuel systems, circuit miniaturization, servo systems, hydraulic pumps, tool engineering, orbit mechanics, telemetry, data processing, wind tunnel testing, etc.): ______

JOBS AND EDUCATION

List your last 3 employers:

EMPLOYER	CITY & STATE	YEARS EMPLOYED	JOB TITLE OR FUNCTION

List your college and university degrees:

SCHOOL	YEARS ATTENDED	DEGREE

Special Training ______________________

PERSONAL DATA

AGE .... U. S. CITIZEN ☐ YES ☐ NO If not, when do you expect to become a citizen? ....

Name: ....

Home Address: ....

Home Telephone: ....

Make sure you have checked the companies you are interested in on the other side of this Form. Then put the Form in a stamped envelope and mail it to **Space/Aeronautics.**

THREE IBM CAREER OPPORTUNITIES WHERE THE COMMON DENOMINATOR IS

MATHEMATICS

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*       P.3       *        :
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*       P.3       *
*                 *
*L(I,K) IS TO 0   *
* GREATER  =  LESS *
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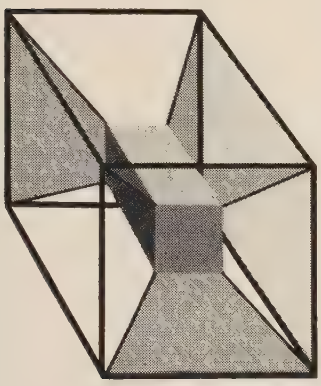
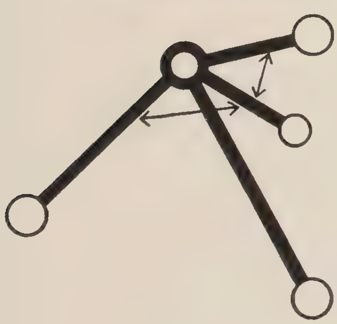
COMPUTER PROGRAMMING at IBM is being extended to include many new areas—such as orbit computation, meteorological satellites, space probes, information retrieval, design automation, real-time systems, and optical studies. As a result, we are greatly expanding our programming staff, creating opportunities for people with various levels of experience. Assignments involve a wide variety of problems in science, business and government.

Qualifications: Degree in Math, Statistics, the Physical Sciences, Engineering or Engineering Science . . . plus one year's programming experience.



MATHEMATICS RESEARCH at IBM involves interesting challenges in a wide variety of areas. These include matrix algebra; logic; mathematical physics; and probability, communication and information theory. Other fields which are also being subjected to intensive study are numerical analysis, combinatorial topology, and operations research.

Qualifications: B.S., M.S., or Ph.D. in Math, Physics, Statistics, Engineering Science, or Electrical Engineering—and proven ability to assume important technical responsibilities in your sphere of interest.



APPLIED MATHEMATICS offers unusually fine opportunities for the math-oriented. You will be asked to apply your knowledge of mathematical and statistical analysis, probability, logic, and coding to advanced computer development problems. Assignments may take you into computer systems design, component engineering, human factors engineering, or feed-back control theory, information and communication theory, inertial guidance, and scientific programming.

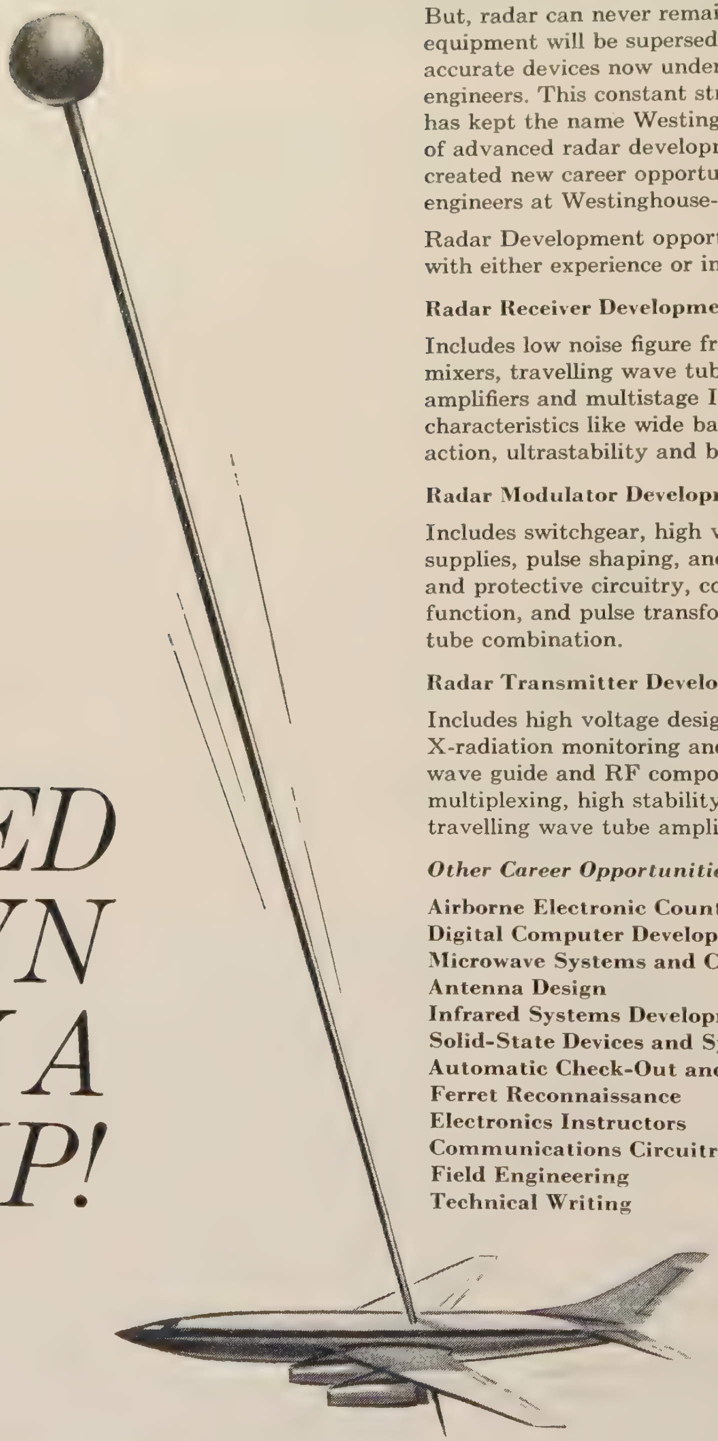
Qualifications: B.S. or Advanced Degree in Math, Physics, or Statistics —plus related experience.

There is a wide and diverse range of career opportunities at IBM. Advancement is rapid. The demands of a constantly expanding program of research and development, and promotion from within, based on individual merit and achievement, make this possible. Working alone or on a small team, you'll find that specialized assistance is readily available.

IBM®
INTERNATIONAL BUSINESS MACHINES CORPORATION

For details, write, outlining your background and interests, to:
Mr. R. E. Rodgers, Dept. 522K
IBM Corporation
590 Madison Avenue, New York 22, N. Y.

Check Employment Inquiry Form on Page 217



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Mr. John J
2469 Wes
Garfiel
New

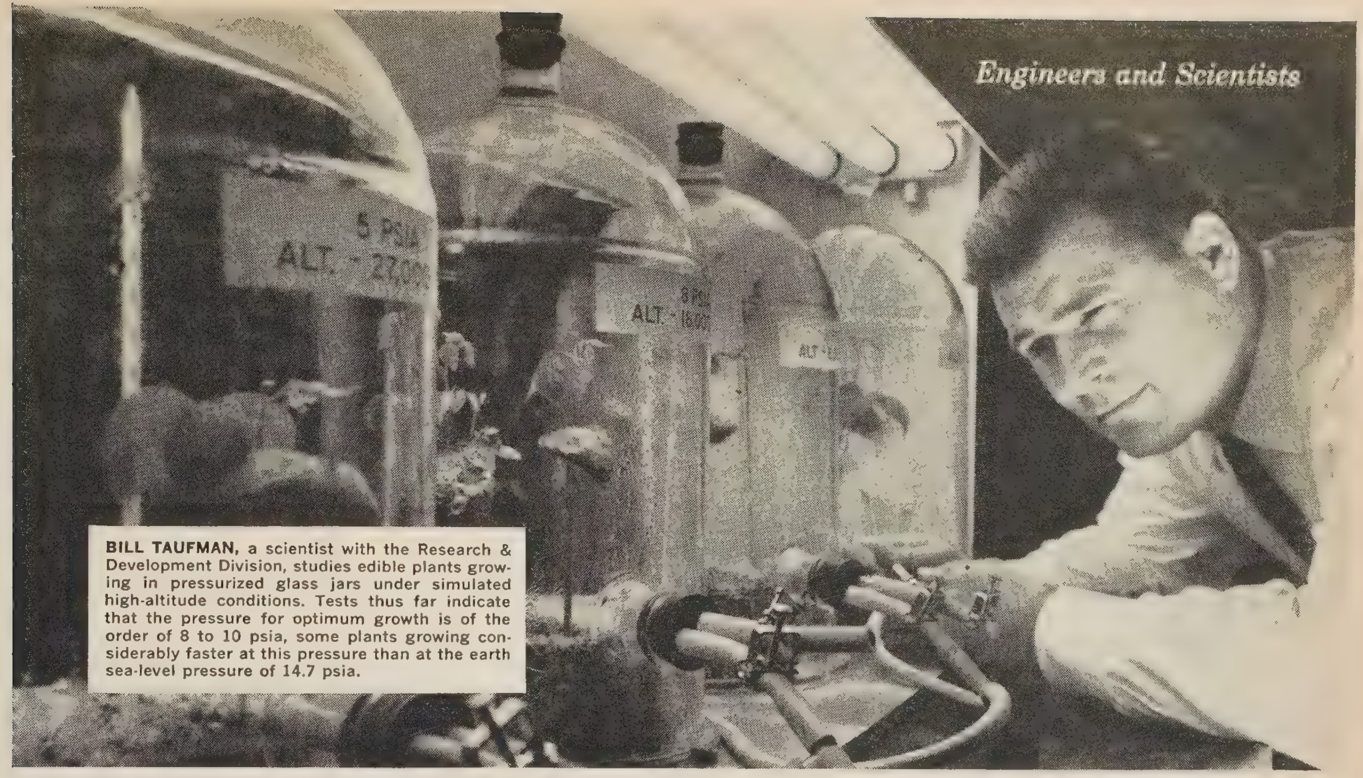
RESUME FROM ROHR

TO PROFESSIONAL AND ADMINISTRATIVE PERSONNEL

Name	Rohr Aircraft Corporation
Address	Main Plant and Headquarters: Chula Vista, California (near San Diego) Manufacturing Plant: Riverside, California Assembly Plants: Auburn, Washington; Winder, Georgia
Age	Established 20 years
Health	Financial health excellent - Sales this year, $184,000,000 Backlog approaching a quarter-billion; 68% commercial
Present Position	World's largest producer of components for flight
Experience	After years of experience in the engineering and manufacture of ready-to-install power packages, Rohr today is widely diversified in many fields of structural flight components. For instance, the design and production of such major components as fuselage sections, jet pods and struts, empennage assemblies, flap tracks, missile racks, wing leading edges, etc. Perhaps even more important is Rohr's leadership in the development and manufacture of stainless steel honeycomb sandwich panels, and advanced research in the field of practical usage of exotic metals.
Reason for these openings	Rohr is selecting successful professional and administrative personnel to join its highly-regarded team.
Business References	America's major aircraft companies
Availability	We are available for interviews whenever it is mutually convenient. Please forward details of your education and experience to Mr. J. L. Hobel, Industrial Relations Manager, Rohr Aircraft Corporation, SA-4 Chula Vista, California

ROHR
AIRCRAFT CORPORATION

Check Employment Inquiry Form on Page 217



BILL TAUFMAN, a scientist with the Research & Development Division, studies edible plants growing in pressurized glass jars under simulated high-altitude conditions. Tests thus far indicate that the pressure for optimum growth is of the order of 8 to 10 psia, some plants growing considerably faster at this pressure than at the earth sea-level pressure of 14.7 psia.

HOTHOUSE ON THE MOON

Studies in low-pressure plant growth for lunar application... just one of the unique programs for engineers and scientists at REPUBLIC AVIATION

An example of the scope of Republic's investigations into every ramification of space exploration is a study to determine the lowest pressure level which will permit normal plant growth. The project is part of an Air Force program to judge the feasibility of a moon base. Another aspect of the study seeks to find the effect of zero gravity on plant growth. Although zero gravity cannot be created on the earth, the potential problems were indicated when plants subjected to negative g, or up-side-down growth, showed only one-half the development of normally grown plants.

Every facet of flight technology, from advanced aircraft design and space vehicle propulsion systems to computer-based trajectory studies for planetary reconnaissance probes, is being explored in Republic's Research and Development program. Distinguished advances have already been made in space guidance concepts, in plasma and nuclear propulsion systems, in radiation physics, in new materials and processing techniques, and in prototype development of hardware (as an example: hydraulic systems that operate reliably up to 1500F.)

These programs will be intensified with the completion – early next year – of Republic's new $14 million Research and Development Center. As the date draws near, staff expansion for these modern facilities is creating in-at-the-beginning career opportunities for senior engineers and scientists capable of sophisticated thinking in theoretical and experimental research. Republic invites qualified individuals to discuss how they can make material contributions to advancing the state of the art.

Opportunities In All Areas of Flight Technology

Electronics

Inertial Guidance & Navigation
Digital Computer Development
Systems Engineering
Information Theory
Telemetry-SSB Technique
Doppler Radar • Countermeasures
Radome & Antenna Design
Microwave Circuitry & Components
Receiver & Transmitter Design
Airborne Navigational Systems
Jamming & Anti-Jamming
Miniaturization — Transistorization
Ranging Systems • Propagation Studies
Ground Support Equipment
Infrared & Ultra-violet Techniques

Thermo, Aerodynamics

Theoretical Gasdynamics
Hyper-Velocity Studies
Astronautics Precision Trajectories
Airplane/Missile Performance
Air Load and Aeroelasticity
Stability and Controls
Flutter & Vibration
Vehicle Dynamics & System Designs
High Altitude Atmosphere Physics
Re-entry Heat Transfer
Hydromagnetics

Plasma Propulsion

Plasma Physics
Gaseous Electronics
Hypersonics and Shock Phenomena
Hydromagnetics
Physical Chemistry
Combustion and Detonation
Instrumentation
High Power Pulse Electronics

Nuclear Propulsion & Radiation Phenomena

Nuclear Weapons Effects
Radiation Environment in Space
Nuclear Power & Propulsion Applications
Nuclear Radiation Laboratories

"Send resume in confidence to: Mr. George R. Hickman, Engineering Employment Mgr., Dept. 6L"

REPUBLIC AVIATION

Farmingdale, Long Island, New York

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Check Employment Inquiry Form on Page 217

ASTRO...

Air-Space Travel Research Organization of The Marquardt Corporation . . .

Offers exceptional engineers and scientists a unique environment for creative research

ASTRO is expanding its facilities, its breadth of interest, and its organization — now offers exceptional career opportunities to outstanding scientists and professional engineers.

Marquardt's ASTRO Division offers creative people a unique environment combining unusually challenging active projects and a lively interest in new ideas. The result: genuine opportunity for significant creative satisfaction.

The men who qualify will join this long-range research group in its new, ultra-modern research center at Marquardt-Van Nuys. The new facility includes a variety of specialized laboratories designed and equipped for applied research in the broad areas of advanced electronics, powerplants, direct energy conversion systems, optics, mechanics and space medicine. From these laboratories will come the new products of Marquardt's Divisions.

If you are a creative scientist or engineer — capable of probing the future, originating new concepts, and then establishing their feasibility — you are invited to consider the following opportunities:

SPACE TECHNOLOGY

Senior Controls System Engineer — For specification generation for systems and for components based on system requirements. Preparation and direction of test programs for systems — performance and environmental. Analysis of closed loop systems, including electronic, pneumatic, and hydraulic components. Components include transducers, prime movers, amplifiers, dampers, etc.

Telemetry Specialist — For applications of telemetry to instrumentation and control systems. A knowledge of instrumentation and controls desired.

Digital Control Expert — For state-of-the-art work in applying digital techniques to guidance and control of space vehicles. Airborne computer experience desired.

Microwave Research Specialist — For research in microwave theory and techniques, both experimental and theoretical.

Research Physicist — For state-of-the-art work in magnetohydrodynamics and related fields. Theoretical and experimental work. Background and experience in field theory or in work related to magnetohydrodynamics.

Energy Conversion Specialist — Broad experience in energy conversion or energy addition in non-chemical power systems. Knowledgeable in both mechanical and electrical systems.

Senior Circuitry Engineer — For design and development of control system circuitry for nuclear power plants.

Guidance Research Specialist — For advanced R & D in guidance systems, and consultation on guidance problems for space vehicles.

Infrared Research Specialist — To study applications of infrared to satellite control, high temperature measurements, horizon scanners, and mapping systems.

Accessory Engineer — For state-of-the-art work in high speed rotating machinery such as hot gas servos, pumps, turbines, bearings.

PROPULSION RESEARCH

Fuels Research Chemist — Experienced in fuels development and combustion process. Familiar with set-up and operation of laboratory concerned with fuel handling, mixing and application.

Aero-thermodynamicist — For advanced air-breathing engine development. Know, or be familiar with internal aero, gas dynamics including dissociation and recombination, chemical kinetics, heat transfer. Prefer B. S. ChE. with advanced combustion system experience.

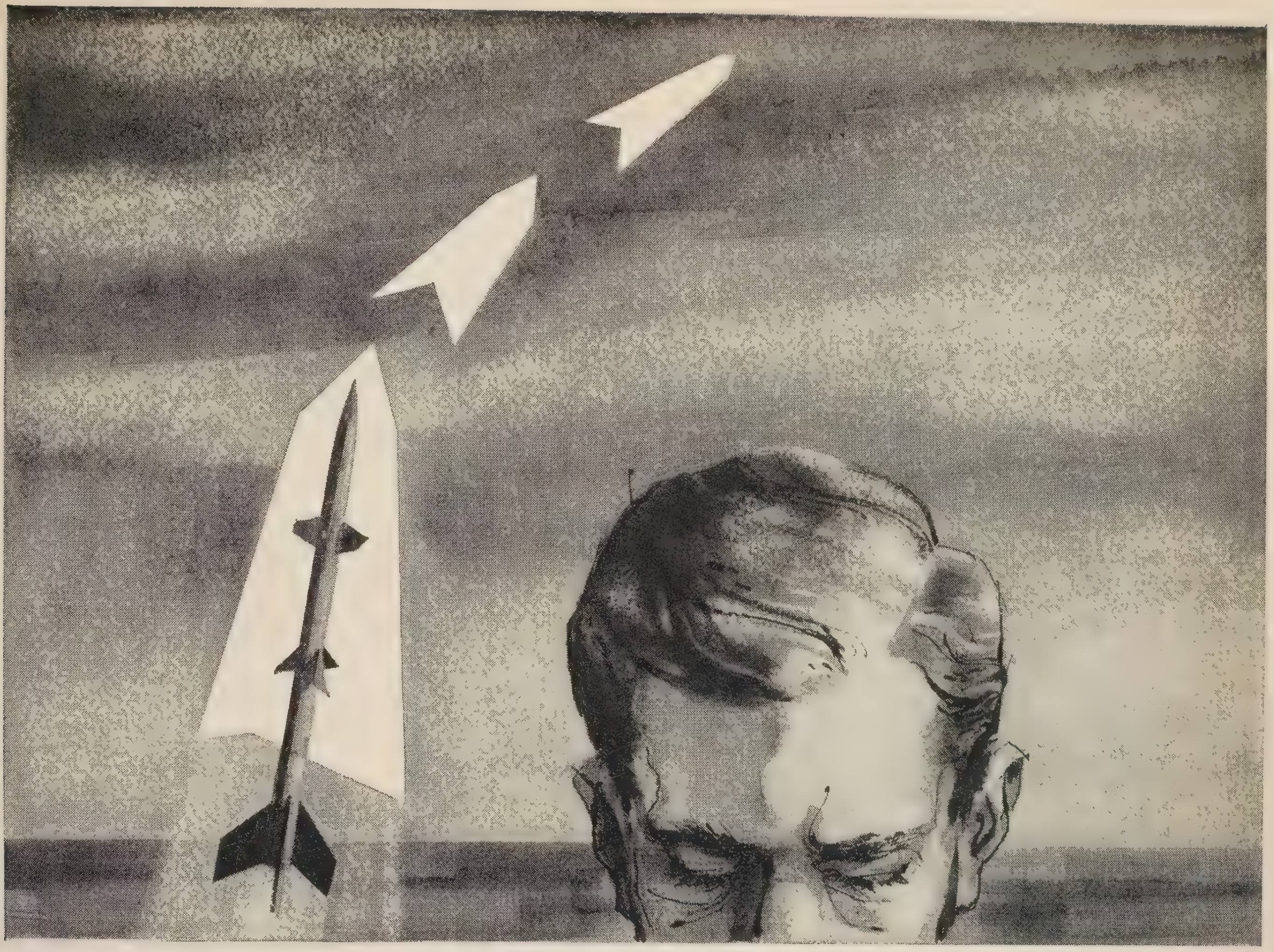
For a copy of our informative brochure "Environment For Engineering," Engineers and Scientists are invited to contact:

Mr. Floyd Hargiss, Manager
Professional Personnel, Dept.
16555 Saticoy Street
Van Nuys, California

THE Marquardt CORPORATION

OPERATIONS AT: VAN NUYS & POMONA, CALIFORNIA — OGDEN, UTAH
SUBSIDIARY: COOPER DEVELOPMENT CORPORATION, MONROVIA, CALIFORNIA
CORPORATE OFFICES: VAN NUYS, CALIFORNIA

Check Employment Inquiry Form on Page 217



Frontiers are extended by the practical visionary

It is the practical visionary who has given us much of what we enjoy today. And it will be the visionary—the man with ability to seek concepts beyond the existing limitations of science—who will guide our developments of tomorrow.

The Applied Physics Laboratory (APL) of The Johns Hopkins University seeks men who will be engaged in advanced research problems—who will find solutions to problems yet to be posed. Their findings will provide guidelines for the space and missile hardware research of the future.

Your endeavors will be heightened by the professional atmosphere of APL. This atmosphere, created by men dedicated to the furtherance of science, has earned APL a reputation as a leader in programs vital to the national security.

Appointments at APL offer exceptional opportunities. For detailed information, address your inquiry to:
Professional Staff Appointments

The Johns Hopkins University Applied Physics Laboratory

8617 Georgia Avenue, Silver Spring, Maryland

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Check Employment Inquiry Form on p 217

Check Employment Inquiry Form on p 217

Check Employment Inquiry Form on p 217

TI Needs More Roy Neely's BS EE, Texas A&M

MANUFACTURING ENGINEERS

Men like Roy Neely are needed for planning and coordinating the design engineering and manufacturing of electromechanical apparatus — engineers who have 3 to 10 years experience with manufacturing processes, tooling, scheduling and costs. Such experience can be used immediately. Your resume will get prompt attention by **John R. Pinkston.**

Department 109

PROFESSIONAL PLACEMENT

APPARATUS DIVISION

TEXAS INSTRUMENTS INCORPORATED
6000 LEMMON AVENUE
DALLAS 9, TEXAS

Check Employment Inquiry Form on Page 217

ELECTRONIC ENGINEERS

...Positions at several levels including supervisory
...High salaries — commensurate with ability and experience

Interesting and challenging positions with Republic Aviation Corporation for electronic engineers to develop test equipment, methods and procedures for determining the conformance of complex electronic equipment to AF and Company quality control specifications and standards.

Work closely with other engineering groups and electronic manufacturers to determine types of equipment required to test and simulate flight operations of radar, navigation, fire control, and other types of electronic systems.

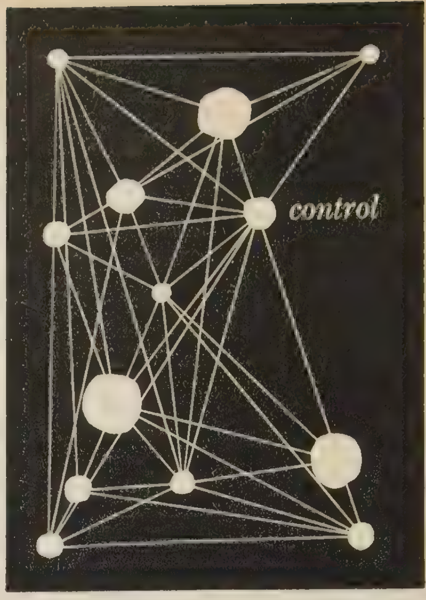
Develop procedures and methods for use of electronic test equipment. Assist supervision with manufacturing problems. Investigate malfunctioning of electronic equipment off and on aircraft. Prescribe corrective action. Make recommendations in methods and procedures as may be required to meet new developments in the electronic fields.

Send resume in confidence to: Mr. William Walsh

REPUBLIC AVIATION

Farmingdale, Long Island, N. Y.
Less than 1 hour from New York City

Check Employment Inquiry Form on Page 217



careers in control of space

For 74 years, Minneapolis Honeywell has pioneered and led the development and production of advanced automatic controls. Today, with work in this area more demanding and more rewarding, new opportunities exist for engineers.

PRODUCTION: Develop and establish assembly processes for a wide range of products. Requires background in complex devices such as gyros, accelerometers, flight systems, and a thorough knowledge of production processes.

EVALUATION: Test engineer interested in career in development, qualification, reliability testing. Must be graduate engineer with electronic background.

ADVANCED GYRO DESIGN: Engineers with two and up to twenty years' experience in such areas as precision gyro mechanics, servo techniques, digital data handling, electronics packaging, advanced instrumentation and magnetic components design.

FLIGHT CONTROL SYSTEMS: Analytical, systems, component engineers to design and develop advanced flight reference and guidance systems. Prefer airborne systems or servo experience.

FIELD SERVICE: Monitor airborne system performance in U.S. and overseas. Conduct training, liaison with military. BSEE preferred, or graduate engineer with high electronic aptitude.

GROUND SUPPORT: Senior engineers with logical design experience and engineers with experience in ground support or related areas. Outstanding growth opportunity in new division.

If you're interested in a challenging career in advanced automatic controls, write Mr. Bruce D. Wood, Technical Director, Dept. 65A.

Honeywell H HONEYWELL
AERONAUTICAL DIVISION

1433 Stinson Blvd., N.E., Minneapolis 13, Minn.

To explore professional opportunities in other Honeywell operations coast to coast, send your application in confidence to H. D. Eckstrom, Honeywell, Minneapolis 8, Minnesota.

Check Employment Inquiry Form on Page 217

For more detailed information... on Products or Service use this "TIME-SAVER" Card

1. *Write* reader service number for each editorial item or advertisement of interest in box on card. (Reader service numbers appear next to all editorial items and advertisements.)

2. Fill out your Name, Title, Company, Address and check industry activity.

3. Tear out and mail . . . no postage necessary. SPACE/AERONAUTICS' Reader Service Department will contact the manufacturer for you.

NAME.................................... TITLE....................................

COMPANY....................................

ADDRESS....................................

CITY.................................... STATE....................................

PRINT READER SERVICE NUMBERS HERE

SPACE/AERONAUTICS
Reader Service Card
NOVEMBER 1959
(Not good after 1-15-60)

Does your work apply to:
(Check appropriate box or boxes)
AIRCRAFT PROJECTS ☐
MISSILE PROJECTS ☐
SPACECRAFT PROJECTS ☐

NAME.................................... TITLE....................................

COMPANY....................................

ADDRESS....................................

CITY.................................... STATE....................................

PRINT READER. SERVICE NUMBERS HERE

SPACE/AERONAUTICS
Reader Service Card
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NAME.................................... TITLE....................................

COMPANY....................................

ADDRESS....................................

CITY.................................... STATE....................................

PRINT READER SERVICE NUMBERS HERE

SPACE/AERONAUTICS
Reader Service Card
NOVEMBER 1959
(Not good after 1-15-60)

Does your work apply to:
(Check appropriate box or boxes)
AIRCRAFT PROJECTS ☐
MISSILE PROJECTS ☐
SPACECRAFT PROJECTS ☐

FIRST CLASS
Permit No. 16734
New York, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed in the United States

POSTAGE WILL BE PAID BY

SPACE/AERONAUTICS

205 EAST 42nd STREET

NEW YORK 17, N. Y.

Reader-Service Dept.

FIRST CLASS
Permit No. 16734
New York, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed in the United States

POSTAGE WILL BE PAID BY

SPACE/AERONAUTICS

205 EAST 42nd STREET

NEW YORK 17, N. Y.

Reader-Service Dept.

FIRST CLASS
Permit No. 16734
New York, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed in the United States

POSTAGE WILL BE PAID BY

SPACE/AERONAUTICS

205 EAST 42nd STREET

NEW YORK 17, N. Y.

Reader-Service Dept.

For more detailed information... on Products or Service use this "TIME-SAVER" Card

1. *Write* reader service number for each editorial item or advertisement of interest in box on card. (Reader service numbers appear next to all editorial items and advertisements.)

2. Fill out your Name, Title, Company, Address and check industry activity.

3. Tear out and mail . . . no postage necessary. SPACE/AERONAUTICS' Reader Service Department will contact the manufacturer for you.

product index to advertising

THIS IS A SPECIAL REFERENCE to the product information given in the advertisements in this issue. It is intended solely to help the reader make the best use of these ads. Therefore the index does not necessarily cover all the products made by each advertiser. Also, cross-listings are not intended to exhaustively describe each product but merely to make sure that each product can be found with reasonable ease by the reader looking for it.

Similar indexes to services and employment opportunities featured in ads follow this index.

Advertisements for which complete proofs were not available to the Editorial Department by the closing date are not necessarily covered by these indexes. (Proofs can be forwarded internally by the Production Department only for advertisements meeting the closing dates.)

For more detailed information on any product or service advertised in this issue or featured in its Product and Data Reviews, use the handy Reader Service Card.

more on next page

PRODUCT INDEX

more on page 234

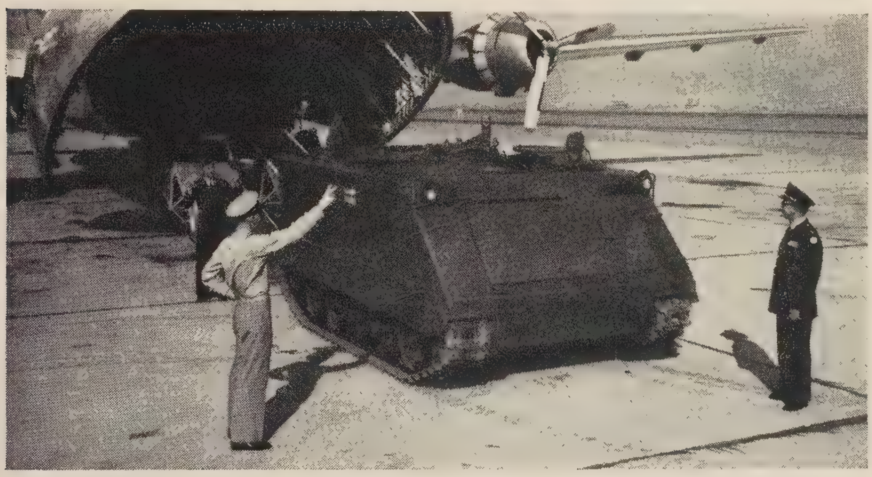
New Kaiser Aluminum Weldable Alloys

Aluminum alloys 5083 and 5086 have been developed by Kaiser Aluminum for welded structures requiring maximum joint strength and efficiency, particularly those subject to impact or dynamic loading.

Kaiser Aluminum alloys 5083 and 5086 are high strength, non-heat-treatable, weldable alloys offering seven distinct advantages:

1. GREATER DESIGN EFFICIENCY FOR WELDED STRUCTURES.
2. SUPERIOR WELDING CHARACTERISTICS.
3. EXCELLENT FORMING PROPERTIES.
4. HIGH RESISTANCE TO CORROSION.
5. ECONOMY EQUAL TO OTHER NON-HEAT-TREATABLE ALLOYS.
6. IMPROVED WELD ZONE DUCTILITY.
7. HIGH STRENGTH IN THE AS-WELDED CONDITION.

These weldable alloys are designed with improved properties for products subject to impact or dynamic loading. They have proved, through extended testing and on-the-job use by many industries, complete reliability under every requirement imposed upon them.



A new amphibious, air transportable and air-droppable aluminum armored personnel carrier, the M113, built by Food Machinery & Chemical Corporation's Ordnance Division, San Jose, California, is shown being loaded aboard an Air Force C-124. The M113 was engineered and developed under the direction of Ordnance Tank-Automotive Command U. S. Army to replace the steel model M59. The hull of the vehicle is primarily made of Kaiser Aluminum alloy 5083 plate, extrusions and forgings.

FASTER WELDS POSSIBLE

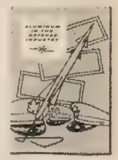
An outstanding characteristic of these high magnesium-aluminum alloys is their ability to take full advantage of inert-gas, shielded-arc welding methods. Fast, superior welds and pressure tight joints are thus assured. These are the strongest A.S.M.E. approved aluminum alloys available for the fabrication of unfired pressure vessels without thermo stress-relieving.

Many military products are now being made better at less cost with Kaiser Aluminum alloys 5083 and 5086. The M-113 track vehicle illustrated in Figure 1 is one example. Others include such products as missile structures and skins, missile containers, cryogenic tanks, radar antenna, destroyer gun mounts, crew boat hulls, bridges, overhead cranes, flatbed trailers and armored and amphibious vehicles.

Available in sheet, plate, forgings and extrusions in annealed and rolled tempers, alloys 5083 and 5086 make possible hundreds of new uses for aluminum in military applications. If you want further information, we'll be glad to assist you. Our staff of specialists in metallurgical research, product engineering and field engineering is at your disposal. Call or write:

Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

FREE! A Complete Portfolio On Aluminum In The Defense Industry



For your information and reference, Kaiser Aluminum offers the complete results of its comprehensive survey of the uses of aluminum in the missile industry—plus data on alloys 5083 and 5086 as used in cryogenics and other military applications. For your free portfolio, write for "Aluminum In The Defense Industry": Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

TYPICAL MECHANICAL PROPERTIES OF ALUMINUM ALLOYS 5083 AND 5086 COMPARED TO ALUMINUM ALLOY 6061 AND MILD STEEL

	5083		5086				6061				Mild Steel
	"0"	"H113"	"0"	"H32"	"H34"	"H112"	"0"	"T4"	"T6"	As Welded	ASTM A201B
Tensile Strength (psi)	42,000	46,000	38,000	42,000	47,000	39,000	18,000	35,000	45,000		60,000 Min.
Yield Strength (psi)	21,000	33,000	17,000	30,000	37,000	19,000	8,000	21,000	40,000		32,000 Min.
Elongation (% in 2")	22	16	22	12	10	14	30	25	17		25
Fatigue Strength, psi		23,000			15,000	22,000	9,000	14,000	14,000		34,000
Ultimate Shearing Strength	25,000		23,000		27,000		12,000	24,000	30,000		42,000
Mod. of Elasticity, psi	10.3×10^6		10.3×10^6				10.0×10^6				30.0×10^6
Estimated Welded Joint Efficiency		91%				91%	100%		96%	67%	100%
Typical Prop. of Sound Welds (Machined Flush)									**Reheat Treated to T6**		
Tensile Strength (psi)		43,500				39,000			43,000	29,000	66,000
Yield Strength (psi)		22,000				17,000			30,500	17,000	55,000
Elongation (% in 2")		16				21			5	5–13	25%
Filler Alloy		5183				5356			5356	5356	E6020

TYPICAL PHYSICAL PROPERTIES

	5086	5083	6061	Mild Steel
Density (lb./cu. in.)	.096	.096	.098	.284
Specific Gravity	2.66	2.66	2.70	7.88
Thermal Conductivity at 25°C (CGS units)	.30	.28	.39	.12
Average Coefficient of Thermal Expansion 68°F to 212°F (approx.)	13.2×10^{-6}	13.2×10^{-6}	13.1×10^{-6}	7.2×10^{-6}
Melting Range (approx.)	1084–1184°F	1065–1180°F	1080–1200°F	2600–2800°F

NOMINAL CHEMICAL COMPOSITION

5086:	Magnesium, 4.0%;	Manganese, 0.45%;	Chromium, 0.10%		
5083:	Magnesium, 4.45%;	Manganese, 0.75%;	Chromium, 0.10%		
6061:	Magnesium, 1.0%;	Copper, 0.25%;	Silicon, 0.60%;	Chromium, 0.25%	
A201B:	Carbon, 0.20%;	Manganese, 0.60%;	Phosphorous, 0.02%;	Sulfur, 0.02%;	Silicon, 0.23%

KAISER ALUMINUM

THE BRIGHT STAR OF METALS

Write in No. 138 on Reader Service Card at start of Product Preview Section

Service Index to Advertising

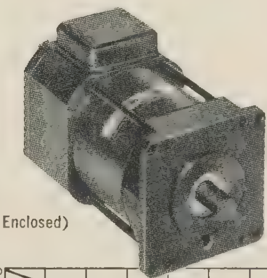
Employment Opportunities Index To Advertising

CLASSIFIED

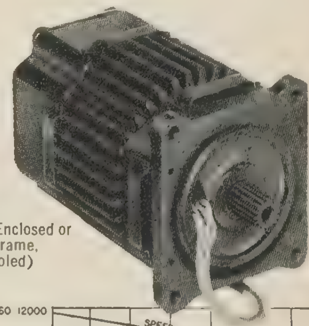
new high-performance motors from AIRBORNE

M-430, 440 Series typify capabilities in meeting special design requirements

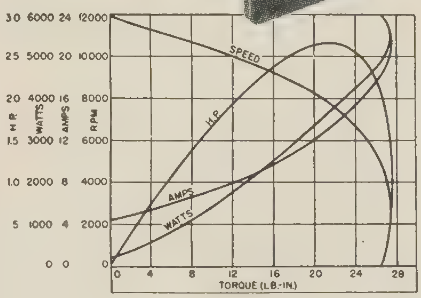
These 400-cycle, 3-phase, 115/200 v a-c motors were developed originally as components of Airborne large special actuators for aircraft/missile applications. Because of their useful performance characteristics, we now offer them separately—both as additions to our line of special motors and as examples of Airborne capabilities in their particular class of application.



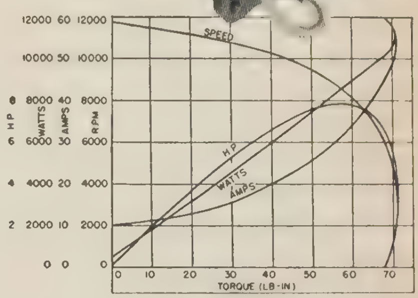
TYPE M-430 (Fully Enclosed)



TYPE M-440 (Fully Enclosed or Open Frame, Fan Cooled)



Typical Performance, M-430 Series, 200 v line



Typical Performance, M-440 Series, 200 v line

M-430 Series, 3-in. frame

Intermittent duty ratings to 1.8 hp; continuous ratings to 1.0 hp. Available with magnetic brake which will stop motors in 22 rev. from no-load speed and provide 30 in.-lb. holding torque. Model shown is a 7.5 lb. brake-equipped motor rated 1.5 hp at 10,000 rpm under a duty cycle of 0.5 min. on, 9 min. off.

M-440 Series, 4-in. frame

Intermittent duty ratings to 5 hp; continuous ratings to 2.5 hp (neither of these are absolute ceilings). Optional brake provides holding torque of 140 in.-lb., stops motors in 20-40 rev. from no-load speed. Model shown weighs 13.2 lb. with brake, is rated 4.0 hp at 10,000 rpm—1 min. on, 1 min. off.

Whatever your requirements in large special high-performance motors—a-c or d-c—it will pay you to check with Airborne. Most likely we can furnish a motor of minimum weight and bulk that will meet exactly your specifications. Write or phone any of our offices.

AIRBORNE®

Engineered Equipment for Aircraft and Industry

AIRBORNE ACCESSORIES CORPORATION

HILLSIDE 5, NEW JERSEY • Offices in Los Angeles and Dallas

Write in No. 140 on Reader Service Card at start of Product Preview Section

KAYNAR MFG. CO., INC.—KAYLOCK DIVISION

Kaylock® ALL METAL SELF-LOCKING NUTS

World's largest and oldest manufacturer of lightweight, all-metal, self-locking nuts. Home office and plant: Box 2001, Terminal Annex, Los Angeles 54, California. Branch offices, warehouses and representatives in Wichita, Kansas, New York, N.Y., Atlanta, Georgia. Canadian Distributor: Abercorn Aero, Ltd., Montreal, Quebec.

Trade Mark

FOR COMPETITIVE REASONS, reappraise your proje
with an eye to "trimming off the fat." Send tod
for Kaynar's new full-line brochure of 160,000 p
self-locking nuts.


H14 6-point Hex Nut


MF1400 Miniatu
Floating Anchor N


K2400 1-Lug Anchor Nut

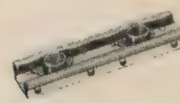

MK1400 Miniatu
2-Lug Anchor N


F2400 1-Lug Floating Anchor Nut


F5400 2-Lug Floa
Anchor Nut


K1400 2-Lug Anchor Nut

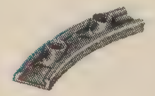

MK4400 Miniatu
Short Lug Anchor


G1400 Narrow Gang Channel


K3400 Corner Ancho


MK2400 Miniature 1-Lug Anchor Nut

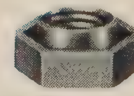

MK3400 Minia
Corner Anchor N


RG1231 Radius Gang Channel


H23 12-Point H
Tensile Nut


H20 12-Point High Tensile Nut


H24 12-Point H
Tensile Nu


H10 6-point Hex Nut

TENSILE STRENG
H10 meets requiremen
MIL-N-25027, AN-N-
AN-N-10 (NAS679) (AR
364, 365) (MS21041
use on 125,000psi.
and screws.

PART NO.	SERVICE TEMP.	TENSILE STRENGTH	MATER
H14	550°F.	160,000psi.	Carbon
MF1400	550°F.	160,000psi.	Carbon
K2400	550°F.	160,000psi.	Carbon
MK1400	550°F.	160,000psi.	Carbon
F2400	550°F.	160,000psi.	Carbon
F5400	550°F.	160,000psi.	Carbon
K1400	550°F.	160,000psi.	Carbon
MK4400	550°F.	160,000psi.	Carbon
G1400	250°F.	160,000psi.	Nuts-Car Channel Allo
K3400	550°F.	160,000psi.	Carbon
MK2400	550°F.	160,000psi.	Carbon
MK3400	550°F.	160,000psi.	Carbon
RG1231	1,200°F.	160,000psi.	Nuts-A CRE Channe CRE
H23	550°F.	180,000psi.	Alloy
H20	550°F.	180,000psi.	Alloy
H24	550°F.	220,000psi.	Alloy
H10	550°F.	125,000psi.	Carbon

All configurations shown are available i
A286 Stainless Steel for high temperature appl

advertisers' index

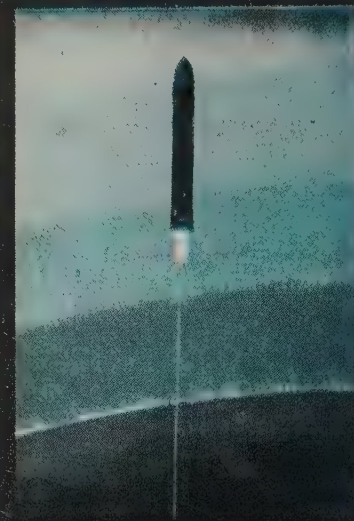
more on next page

To further serve the diversified missile industry

MINNESOTA MINING and MANUFACTURING COMPANY

announces and offers the services of its

MISSILE INDUSTRY LIAISON



More than 27,000 products are manufactured by Minnesota Mining and Manufacturing—the 3M Company. Every day, more and more 3M products are playing important parts in missile and space operations.

The technical and sales staffs of some fifteen 3M divisions, subsidiaries and groups make daily contacts with missile manufacturers and subcontractors. Their efforts are implemented by 22 divisional and four staff research laboratories.

However, like the missile industry, the 3M Company is a growing *and a diversified* operation. The use of 3M products and capabilities increases every day.

To further serve this growing, diversified industry, 3M has formed the Missile Industry Liaison. This group, staffed by technical personnel experienced in rocket propulsion and other phases of space technology, is well qualified to translate *your problems* to those 3M specialists in your field of interest. Too, information on all 3M Company products—or interests applicable to missile research, development or production—is thus available to you through *one* convenient source.

For a cross-section view of 3M Company products for the industry, send for your free copy of the brochure "Products and Capabilities." Write: Missile Industry Liaison, 400 McKnight Road, St. Paul 6, Minnesota.

The Missile Industry Liaison is associated with these 3M divisions and subsidiaries:

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American Lava Corporation
Irvington Division
Mica Insulator Division
Magnetic Products Division
Central Research Group
Mincom Division
Duplicating Products Division
Reflective Products Division
Industrial Trades Tape Division
Mid-States Gummed Paper Division
Chemical Division
Adhesives, Coatings, and Sealers Division
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For more information on 3M products, contact your 3M representative or the Missile Industry Liaison, 400 McKnight Road, St. Paul 6, Minn.

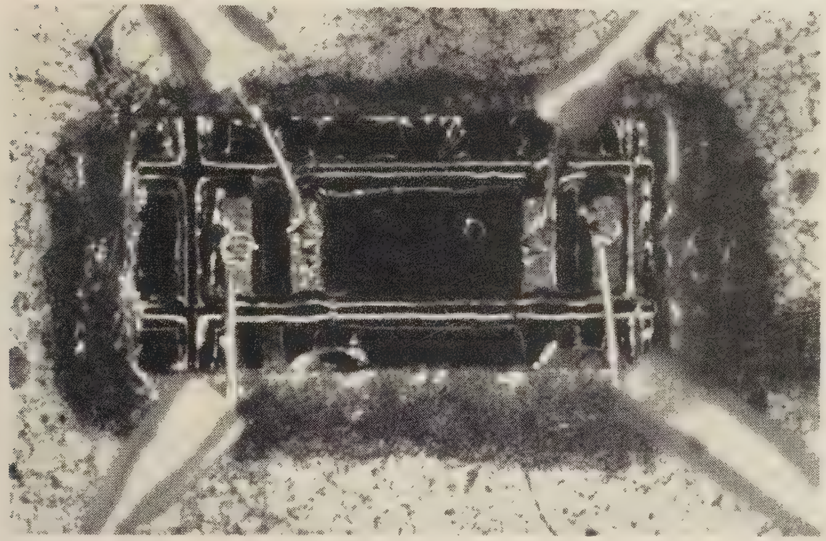
MINNESOTA MINING AND MANUFACTURING COMPANY
...WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

MISSILE INDUSTRY LIAISON

Write in No. 144 on Reader Service Card at start of Product Preview Section

equipment briefs



STEPPING TRANSISTOR

A NEW transistor element developed at Bell Telephone Laboratories, 463 West St., New York 14, N.Y., is shown here magnified about 45 times. Essentially, the four-terminal device acts as a pulse-controlled on-off switch. Forming the basic building block of a silicon stepping transistor, it can be used as a basic stage for certain logic circuits in digital computers, as for counting and decoding.

The element is mounted on a gold-plated Kovar header. The leads are thermo-compression-bonded to gold-silver alloy contacts. The stepping transistor can be made either of interconnected elements or on a single piece of silicon. In the latter form, it follows the "functional device" approach to microminiaturization.

The stepping transistor itself is the result of research at Bell Labs that was begun during 1954. The aim of this work was to build a semiconductor device that would emulate the function of a gas stepping tube, particularly as a high speed digital counter.

Presently in prototype form, the transistor uses a PNPN device as the bistable element. The resulting structure has a bistable voltage-current characteristic between a single common electrode and a set of multiple electrodes. Asymmetric geometry is used to get unidirectional voltage transfer.

Unlike the gas stepping tube, the transistor doesn't require close proximity between stages. Its elements, which make up separate four-terminal stages, therefore can be encapsulated separately and connected externally.

The operating current level is 1-100 ma with supply voltages of 10-100 V. Prototypes have been operated at speeds of up to 1,000,000 pps. Write in No. 65 on Reader Service Card for more information.

HOT-GAS MOTOR

A NEW energy converter developed by Vickers Inc., Detroit 32, Mich., for hot-gas system operation is based on the design of the company's standard piston-type hydraulic motor.

Important differences are the use of special heat-resistant materials and improved contaminant tolerance. Also, the valve has been modified to permit optional gas inlet cutoff (partial admission) for adiabatic expansion. The unit shown here weighs 2.5 lb and can put out 8.9 hp.

The motor can run off propellant-generated gases or hot gases bled from the prime propulsion system. In its development program, Vickers used solid propellant generators that provided gas pressures of 1000-2000 psi and combustion supply temperatures of up to 2300 deg F. Over 100 runs have been made on single units, says Vickers, each run averaging over a minute.

In one series of tests, Vickers used the products of the combustion of hydrogen and oxygen. It reports that, despite combustion temperatures of over 5000 deg F, the test motor showed no ill effects. Write in No. 56 on Reader Service Card for more information.

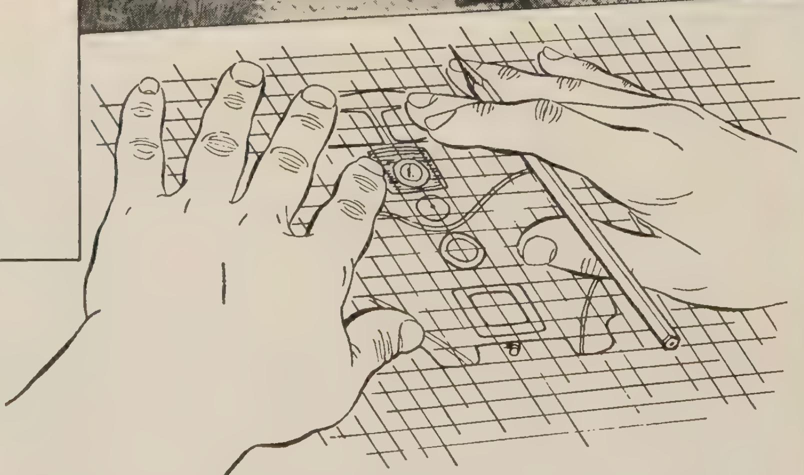
INFRARED COOLER

A TINY cooling device that super-chills infrared detection equipment to 60 deg K (—350 deg F) has been developed by Arthur D. Little, Inc. The eight-ounce device is the result of a two-year study of extreme low temperature equipment. The miniature closed-cycle cooler is suited to operation in aircraft and missiles.

Helium expands under 300 psi in a two-inch-long, ¼-in.-diameter cylinder. The only moving part is a tiny plastic piston that operates below room temperature. Hamilton Standard Div., United Aircraft Corp., Windsor Locks, Conn., produces the device under license from ADL. Write in No. 66 on Reader Service Card for more information.

The Hand with the GOLDEN TOUCH uses A.W.Faber-Castell with BLACK GOLD Graphite

"Sunset" Photo courtesy of The Budd Co. and Southern Pacific Railroad.



Engineers, architects, designers and draftsmen agree that there is enough agony in the creative process without inferior pencils adding to it. Whether your job is to conceive or interpret, your work is easier with CASTELL, the drawing pencil with Black Gold Graphite that gives the "Golden Touch" to your fingers.

CASTELL gives wings to the flight of your imagination. It glides without grit or hard spot. More than 99% pure carbon, CASTELL gives true value in each of 20 superb degrees, 8B to 10H. One degree gives you gossamer-thin lines, another gives you bold blacks. It's your perfect transfer agent that transforms your grey matter into black matter.

It costs no more to work with the world's finest drawing tools—imported CASTELL wood pencils, CASTELL lead and new functional design LOCKTITE TEL-A-GRADE holders, with the bulldog grip clutch. Order from your dealer today.

Choose from: **#9000** CASTELL Pencil. **#9007** CASTELL with Eraser. **#9800SG** LOCKTITE TEL-A-GRADE Holder with new functional spiral grip and degree indicating device. **#9030** CASTELL Refill Lead matching #9000 pencil in quality and grading, packed in reuseable plastic tube with gold cap. Other styles and colors of pencils, holders and refill leads.

Castell Leads and Pencils draw on all surfaces, including Mylar-based polyester drafting films. Give perfect lines, easy to erase —excellent reproduction.

BACKED BY NEARLY 200 YEARS UNINTERRUPTED MANUFACTURING EXPERIENCE — SINCE 1761

FABER-CASTELL

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A.W.FABER-CASTELL Pencil Co., Inc.
Newark 3, N. J.

Write in No. 145 on Reader Service Card at start of Product Preview Section

space aeronautics

product of the month

TAPE RECORDER weighs 10½ ounces

Feature Product Award

NOVEMBER 1959

Leach Corp., 5915 Avalon Blvd., Los Angeles 3, Calif., has developed a 10½-oz. tape recorder that records data on space vehicles or underground drilling with equal facility. It is so small that even a child can hold it in its hands (as in this picture). Leach claims it is the smallest recorder in the world. It will register information about air or space flight on 1-16 channels on a continuous tape, which will then play back to earth receivers. The recorder has a high resistance to shock (over 2000 g) and an extremely low power consumption of 1½ W. It occupies 14 cubic in. of space.

The recorder considered to be the world's smallest before the development of this one weighed 24 oz and was also developed by Leach.

Write in No. 146 on Reader Service Card at start of Product Preview Section

This award is made in recognition of outstanding service performed through the development and manufacture of a product contributing to the advancement of the aerospace industry.

Randolph Hawthorne
Editor

product preview

SPINDLES *feature electrolysis*

"Endless versatile variations" in design, sizes, and accessories are claimed for its line of "super precision "spindles by **The Standard Electrical Tool Co., Dept. S/A, 2488 River Rd., Cincinnati 4, Ohio.** Power and speed can be varied from 1 to 20-hp and 600 to 7600 rpm, respectively. Depending on the application, multiple speed on direct motor drive or variable speed on belted motor drive can be used.

DC power supplies from 50 to 3000 amp may be used with current spindle designs. Electrolytic material removal is done by low-voltage, high-amperage dc delivered by a power supply that converts ac from an ordinary power source.

Write in No. 293 on Reader Service Card

COAX-COUPLER IS *extremely flat*

Limiting frequency response variation to only 0.2 db over a full octave these couplers also present a deviation of mean value from nominal of only ±0.3 db, says **Narda Microwave Corp., Dept. S/A, 118-160 Herricks Rd., Mineola, N.Y.**

Vibration accuracy is ±0.1 db. Six models cover a frequency band from 240 to 1100 mc with a nominal coupling value of 20 db.

Write in No. 294 on Reader Service Card

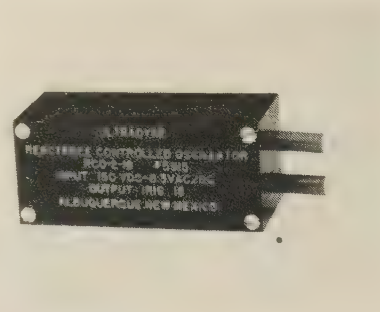
CASTING RESIN ABSORBER *for waveguides*

Eccosarb CR is a casting resin which can be used to mold to size waveguide terminations, attenuators and loads. When cured, it has a high attenuation over the full microwave frequency range, says **Emerson & Cumming Inc., Dept. S/A, 869 Washington St., Canton, Mass.**

Eccosorb CR is supplied as a 2-component liquid system. The material can be cured to a rigid plastic which will reproduce mold dimensions accurately. It can then be readily machined, if required. Cure can be done at room temperature or rapidly at elevated temperature.

Write in No. 295 on Reader Service Card

SUB-CARRIER OSCILLATOR *is reactance controlled*



Model RCO-2 reactance controlled modulator is designed for use with Ultradyne single-coil pressure and acceleration transducers where it is desirable that the transducer and the oscillator be separated, says **Ultradyne Inc., P.O. Box 3308, Albuquerque, N.M.**

The unit is furnished for operation at any of the IRIG bands, as well as subcarrier frequencies much higher. When the oscillator is used with Ultradyne Types S-60-TG and S-90-TG pressure transducers or Types A-60-TG and A90-TG accelerometers, nonlinearity does not exceed ±1 per cent.

Write in No. 296 on Reader Service Card

RF POWER AMPLIFIER *for telemetry transmitters*

Model A-25 Power Amplifier features miniature construction, stabilized circuitry, and improved thermal characteristics. A full 25 watts output is obtained with a 2 watt input drive, input and output nominal 50 ohms in the 215 to 260 megacycle band, says **Daisett Labs, Inc., Dept. S/A, 401 East Boyd, Box 862, Norman, Okla.**

Only 42 cu. in and 1.5 lb, the supply requirements are 450 volts, plate; 225 volts, screen; and either 6.3 or 12.6 ac/dc, filament. Unique circuitry and sectionized mechanical construction permits full power operation without the need of blowers or other forced air cooling method.

Write in No. 297 on Reader Service Card

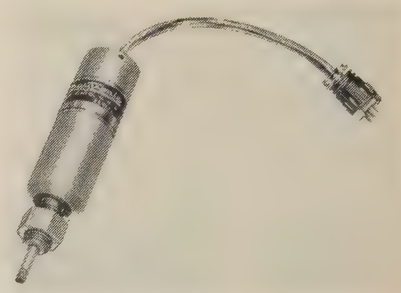
SILICON RECTIFIERS *are efficient*

Each unit in this series of high-quality silicon rectifiers for military and industrial applications offers peak inverse voltages of 100 through 400 V. One-cycle average reverse current is limited to 150 microamp maximum when rectified output is 250 ma and ambient temperature is 150 deg C, says **Motorola, Inc., Semiconductor Products Div., Dept. S/A, 5005 E. McDowell Rd., Phoenix, Ariz.**

Forward rectified currents are 1.5 amp and 250 ma at 25 deg C and 150 deg C ambient. The welded, hermetically sealed, single-ended package is designed for use with both printed circuit and chassis construction. Units are designated INI563A through INI566A.

Write in No. 298 on Reader Service Card

TRANSDUCER *for linear motion*



Linear motion measurement or gaging with accuracy to .0001 in in ranges up to .120 in is accomplished with this model 102A-120 displacement transmitter which provides an electrical output precisely proportional to displacement of its spring loaded plunger, says **Daytronic Corp., Dept. S/A, 216 S. Main St., Dayton 2, Ohio.** A threaded shank and lock nut allow secure and precise positioning in a simple mounting flange.

An inductance device, the unit is said to have no sliding electrical contacts, maintains calibration indefinitely, and is relatively unaffected by mechanical shock, temperature or atmospheric pollution.

Write in No. 299 on Reader Service Card

OXYGEN HOSE *resists fraying, snagging*

This oxygen hose is not subject to fraying and snagging and is said to offer increased flexibility as well as being highly resistant to abrasion and scuffing, according to **Dayton Rubber Co., Strato-Safety Mfg. Div., Dept. S/A, Torrance, Calif.** It meets all MIL-T-7138 specifications.

Write in No. 300 on Reader Service Card

more on page 247

No. 14 • Mars Outstanding Design Series

SQUARE WHEELS? Yes ... square wheels. Operating by means of a floating axle and cam gear, they take the bumps out of rough terrain and provide more traction. U.S. Patent No. 2786540 has been granted to designer Albert Sfredda of Bethlehem, Pa., for his invention.

The square shape gives superior traction in mud, sand, snow or uneven terrain. The flat surfaces of the wheels bridge the ruts instead of sinking into them as do round wheels. The wheels can be in any relative position, do not need to be synchronized—yet they run smoothly. Designed for use on heavy trucks, jeeps, farm or construction machinery, speeds up to 35 miles per hour can be attained.

This ingenious departure from age-old precedent is just one example of the contributions that today's designers are making. To help them translate their pace-setting ideas from concept to reality they require the best of drafting tools.

In pencils that means MARS, long the standard of professionals.

Among the famous imported Mars drafting products are: **Left** — 1001 Mars-Technico push-button lead holder. **Above** — 1904 Mars-Lumograph drawing leads, 18 degrees, EXB to 9H. **Below** — 2886 Mars-Lumograph drawing pencils, 19 degrees, EXEXB to 9H; 2830 Mars-Lumograph Duralar—for drafting on Mylar®-base tracing film — 5 special degrees, K1 to K5; Mars-Lumochrom colored drawing pencils, 24 shades. **Not shown** — Mars Pocket-Technico for field use; Mars pencil and lead sharpeners; Mars Non-Print pencils and leads.

Mars Products are available at better engineering and drafting material suppliers.

® T.M. FOR duPONT'S POLYESTER FILM

for the man who's going places...

the pencil that's as good as it looks **MARS**

Sold at all good engineering and drawing material suppliers • J. S. STAEDTLER, INC. • Hackensack, N. J.

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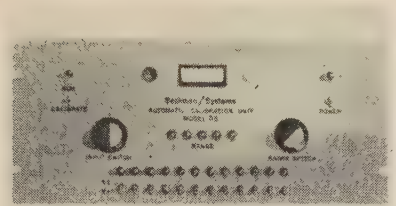
CALIBRATION UNIT
provides accurate voltages



The Model 55 Calibration Unit is an automatic voltage calibrator designed to provide a highly accurate signal source for checking the accuracy of voltage signals, says **Beckman Systems Div., Dept. S/A, 325 No. Muller Ave., Anaheim, Calif.**

The unit may be used manually or automatically with 12 measuring devices and their associated transducers. A remote calibration run may be programed into the unit by using 5 available remote control leads.

Write in No. 365 on Reader Service Card

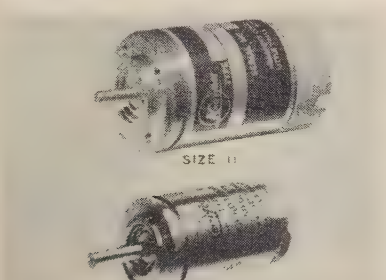
STORAGE SYSTEM
uses nuclear energy

Energy storage systems powered by nuclear batteries and capable of storage densities exceeding 10 million ergs/cubic inch are announced by **Radiation Research Corp., Dept. S/A, 1114 First Ave., New York 21, N.Y.** The basic unit utilizes a nuclear battery with a specially designed low leakage, high voltage, storage capacity and a voltage regulator tube for applications requiring constant available energy over long periods of time.

The nuclear battery uses Krypton 85 and is said to be free from the hazards of ingested radioactivity.

Write in No. 366 on Reader Service Card

PRECISION SYNCHROS
perform at high temperatures



SIZE 11

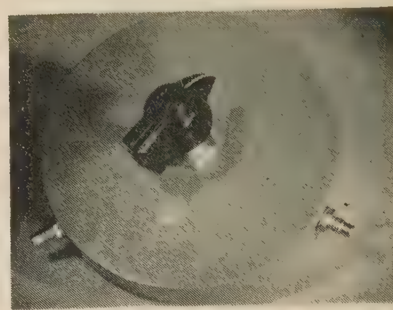
SIZE 8

A series of size 8 and size 11 synchros are designed to operate effectively over a temperature range of −54 deg C to +200 deg C says **Kearfott Co., Inc., Dept. S/A, 1500 Main Ave., Clifton, N.J.** Both types are 400 cps synchros and have a maximum error from electrical zero of 10 minutes.

Write in No. 367 on Reader Service Card

more on next page

DELAY LINES are potentiometer type



This standard potentiometer model comes in a conventional 3 in dia case, with delay time varying from 3 to 30 usec., says **Deltime, Inc., 608 Fayette Ave, Mamaroneck, N.Y.**

The shaft rotation is 210 deg. A locking device can be provided for high vibration applications. Delay lines are available on special order, with delay times ranging into the millisec.

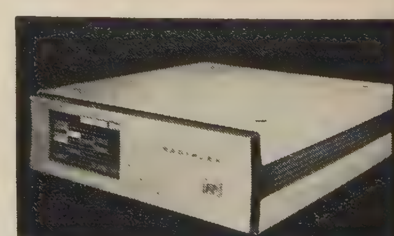
Write in No. 368 on Reader Service Card

STAINLESS ALLOYS are strong and hard

A group of molybdenum containing alloys of the 18-8 type and designated as PH55 series have high strength and hardness with great resistance to corrosion, particularly of the pitting type and to the effects of velocity and suspended abrasions, according to **Copper Alloy Corp., Dept. S/A, Hillside, N. Y.** In the high temperature field (1000-1400 deg F) these alloys are said to be suitable in applications where corrosion resistant parts are subject to stress and shock.

Write in No. 369 on Reader Service Card

ELECTRONIC COMMUTATOR has 24-Kc sampling rate



The Radiplex Commutator is available in two models. The high-level unit has a full-seal input of ±10V with a resolution of ±10uV, says **Radiatron Inc., Dept. S/A, P.O. Box 37, Melbourne, Fla.**

Both models have a 50-channel capacity and a 24 kc sampling rate. Other features include complete solid-state circuitry, asynchronous operation, high common-mode noise refection, and self contained power supply.

Write in No. 370 on Reader Service Card

more on page 251

SEALED RELAYS—unmatched for reliability

All the dust in this room could hide under this dot

This is General Electric's "white room," where special, ultra-reliable miniaturized relays are painstakingly adjusted, inspected, and tested. On certain supercritical applications, particularly those involving dry-circuit switching, a tiny speck of dust could cause a sealed relay to malfunction, possibly resulting in failure of an entire electronic system.

To prevent such costly failures, General Electric has installed this special "white room" where elaborate precautions are taken to maintain a dust-free atmosphere for assembly of ultra-reliable sealed relays. Regular checks insure that dust in the air does not exceed 20,000 particles per cubic foot. Compare this with well over a million particles per cubic foot in the average home or office.

But this dust-free assembly room is only part of General Electric's reliability story. Design leadership, such as produced the Unimite—world's smallest one-amp relay—and advanced manufacturing techniques—including a new inert-arc welding process to eliminate contact-contaminating solder and flux—consistently produce superior relays. Then, General Electric conducts exhaustive operational and environmenta tests to prove extreme reliability.

Relay applications differ widely i performance requirements. Whateve your application, General Electric ca offer sealed relays designed, built an tested to comply with your requir ments. Call your G-E Apparatus Sal Engineer today or mail the coupon right. General Electric Co., Specialt Control Dept., Waynesboro, Va.

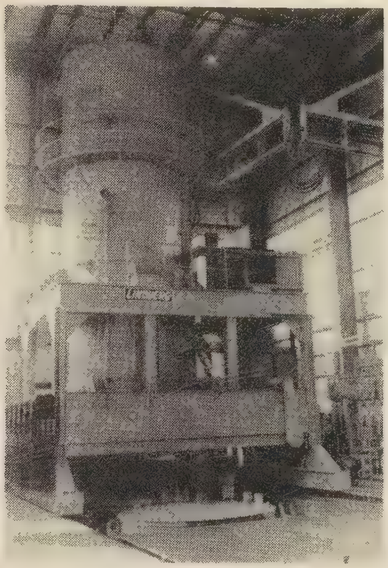
Progress Is Our Most Important Product

GENERAL ELECTRI

Write in No. 151 on Reader Service Card at start of Product Preview Section

PRODUCT PREVIEW

GANTRY FURNACE for rocket motor cases



This controlled atmosphere hardening furnace with bottom loading and discharging, spans a pit containing an atmosphere quench chamber, a salt quench tank, rinse tank, and draw furnace. It is designed for use in production of rocket motor cases. The furnace shell, 11′ in diameter x 35′ deep, is welded gas tight throughout to prevent contamination of the atmosphere by air infiltration and will accommodate a loading fixture with an effective work load 24′ long by 6′ 8″ in diameter. Heating elements employed for temperatures to 2050° F are of 80% nickel—20% chromium analysis and are mounted on the refractory in tiers so as to provide 500 KW in five zones of control, says **Lindberg Engineering Co., Dept. S/A, 2450 W. Hubbard St., Chicago 12, Ill.**

The furnace is mounted on four wheels on 18′ centers with rails which allow the furnace to travel along the 57′ length of the furnace pit.

Write in No. 371 on Reader Service Card

DRIVER TRANSISTORS have a current gain of 150

These germanium driver transistors can be used in audio amplifiers, audio oscillators class A and B amplifiers, power switches, servo control, relay drivers and motor controls, says **Bendix Aviation Corp., Red Bank Div., Dept. S/A, Eatontown, N.J.**

Designated 2N1008-A-B and contained in the JEDEC TO-9 package, dissipates 400mw at 25 deg C and 67 mw at 75 deg C. The series has a voltage range from 20 to 60 V, and a maximum current gain of 150 combined with high linear current gain characteristics to permit switching application and lower distortion output.

Write in No. 372 on Reader Service Card

more on next page

SPACE CLOTH *has controlled resistivity*

A series of thin sheet materials of controlled resistivity, dielectric constant and dissipation factor for use in a variety of microwave applications has been announced by **Emerson & Cumings, Inc., Dept. S/A, 869 Washington St., Canton, Mass.** Uses include the lining of cavity interiors to lower Q, preventing flow of high frequency currents from a radiating surface, terminating waveguides, and modifying antenna patterns.

The material is available in four types of woven fabric or in a flexible plastic sheet form. The plastic type and one of the fabric types have a surface resistivity of 377 ohms per square, or the impedance of free space, making these materials suitable for many unique uses. The Eccosorb SC series of materials also merits consideration for use in resistors, potentiometers, RF gaskets, and electrostatic shields.

Write in No. 375 on Reader Service Card

NEUTRON DOSIMETER *uses dry batteries*

A transistorized fast neutron dosimeter, operated on flashlight batteries, designated E-1B, is said to promote safety among personnel working with nuclear materials by providing an indication of radioactivity proportional to the effect on human tissue of fast neutrons associated with nuclear technology, according to **Nuclear Corp. of Amer., Dept. S/A, 400 Park Ave., New York 22, N.Y.**

The instrument, weighing under 7 lbs., uses 10 flashlight cells and is separated into a probe and an electronic unit for ease of handling.

Write in No. 376 on Reader Service Card

RACK CONNECTORS *are snap-in types*

Snap-in contacts and crimp-type terminations have been designed into the DRS series of rectangular rack-and-panel connnectors made by **The Deutsch Co., Dept. S/A, 7000 Avalon Blvd., Los Angeles 3, Calif.** The spring-mounted connectors, made for module units, are self-aligning up to 1/32-in. misalignment in either the drawer or the panel mounting; pushing the drawer into place assures complete mating.

The connectors are available in 49 and 99 contact sizes, and they have #20 contacts. Operation is possible to 110,000 ft and over a –70 to +392 deg F.

Write in No. 377 on Reader Service Card

CHAMBERS *have full visibility*

A full-view, extra-strength Plexiglas dome gives maximum visibility to these controlled atmosphere chambers designed for fast atmosphere pump down. Ultimate vacuums of 5×10^{-4} can be reached in less than 20 min, says **Scientific Engineering Laboratories, Dept. S/A, 1510 Sixth St., Berkeley 10, Calif.** The chambers can easily provide controlled atmospheres with contamination less than one part per million, without relying on excess inert gas flushing.

In standard models, chamber pressures can be reduced to under 1×10^{-4} mm hg before introduction of the desired uncontaminated atmosphere. The usefulness of the chambers is increased by large feed through the ports, and the devices are available with a wide variety of fixtures, welding systems, furnaces and ovens, and feed throughs.

Write in No. 378 on Reader Service Card

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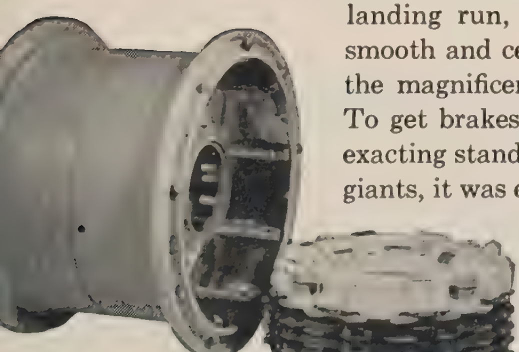
JETLINERS DEMAND JET-AGE BRAKES



From touch-down to the end of the landing run, Bendix brakes provide smooth and certain ground control for the magnificent new jet airliners . . . To get brakes that measure up to the exacting standards of these swept wing giants, it was entirely logical to look to the world's most experienced supplier . . . For similar reasons, Bendix brakes are regular equipment on the largest and fastest military jets, as well as fully certified by FAA for the new civilian jets . . . BRAKES BY BENDIX is another important reason why you can fly the jetliners with complete assurance.

Bendix PRODUCTS DIVISION South Bend, IND.

Bendix AVIATION CORPORATION

The Log of the Navy's Polaris

1958 In January, just a year after the Navy had announced its plan for a Fleet Ballistic Missile, the first Polaris test vehicle was suc-cessfully fired. Firings continued throughout 1958. By Septembe the test vehicles were close to the final configuration of the Polaris

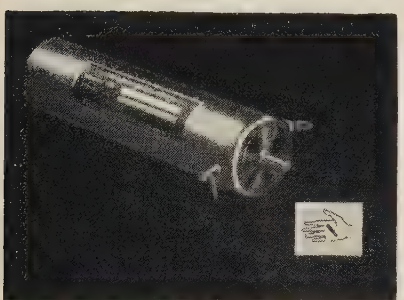
SMALL BATTERIES *have high potential*

A group of solid state batteries, small enough to hold in the palm of your hand but capable of delivering a combined voltage of 1600 V, are now available, says **Patterson, Moos Div., Universal Winding Co., Dept. S/A, 90-28 Van Wyck Expressway, Jamaica, N.Y.**

Called Dynox, they come in four different sizes—Dynox 95, 95 V potential in 0.14 cu in., Dynox 190, 190 V potential in 1.15 cu in., Dynox 380, 380 V potential in 1.57 cu in., and Dynox 950, with a 950 V potential in 2.87 cu in. The latter is said to be the smallest solid state battery on the market with such a high voltage rating.

Write in No. 421 on Reader Service Card

INERTIA SWITCH *is compact, light*



This inertia switch is compact, light, reliable, accurate and meets military environmental requirements. It can be mounted in any plane to detect acceleration forces caused by roll, pitch, yaw, etc., says the **Magnavox Co., Dept. S/A, Fort Wayne, Ind.** Standard units are factory adjustable from 1 G to 3 G and special units up to 50 G can be constructed.

Operating temperature range −55 deg C to 100 deg C. Accuracy ±5 per cent, time constant at 25 deg C is 1 sec. Switch reset is automatic and contacts rated 100 milliamperes at 28 vdc.

Write in No. 422 on Reader Service Card

SERVO MOTOR *meets BuOrd specifications*

What is reported to be the first Size 8 servo motor developed to BuOrd specifications (Mark 23, Mod 1) has been offered by **John Oster Mfg. Co., Dept. S/A, 1 Main St., Racine, Wisc.** The Type 5002-04 has a .35 oz-in stall torque, a 24,700 rad/sec torque-to-inertia ratio, and a rotor movement of inertia of ten gm cm^2.

No load speed is 6200 rpm. The 1.6-oz unit is provided with a 26-V fixed phase and a 36-V center tapped control phase for transistor applications.

Write in No. 423 on Reader Service Card

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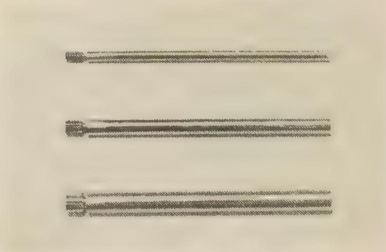
PINION SHAFTS in stainless steel



These type F precision pinion shafts, in 24, 32, 48, 64, 80, 96, 120 or 200 pitch, with 20 deg pressure angle are available in no. 303 stainless steel, with a clear passivated finish after gear cutting, says **PIC Design Corp., Dept. S/A, 477 Atlantic Ave., E. Rockway, L.I., N.Y.**

Write in No. 381 on Reader Service Card

TRANSDUCER SYSTEM for measuring lox

This airborne Servo Transducer System, Leonard Model 502400-2, for continuous measurement of Lox or fuel head in missiles can measure the height of a column of liquid within very close tolerances. Typical values for a 22 ft column are: repeatability 0.040 in. and hysteresis 0.080 in. states **Wallace O. Leonard, Inc., Dept. S/A, 373 So. Fair Oaks Ave., Pasadena 1, Calif.**

This system features two potentiometer outputs, one fine the other coarse. Optional outputs include code generators, synchros, potentiometers or combinations of these.

Write in No. 382 on Reader Service Card

SOLDERING TOOL eliminates arcing

This soldering tool eliminates arcing and provides high speed, void free connections critical in the aircraft and missile industry, according to **General Electric Co., Industrial Heating Dept., Dept. S/A, Schenectady 5, N.Y.** It is automatic and particularly adaptable to soldering multiple prong plugs.

In a single step operation, it provides even heating temperature throughout the work and produces void free solder joints on the most critical connections, it is said.

Write in No. 383 on Reader Service Card

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SILICON TRANSISTORS *for high frequency applications*

These 7 high-frequency silicon transistors are designed for both amplifier and switching circuits and are JEDEC type designated 2N332 to 2N338. Their fixed bed mounting using a ceramic disk results in an extremely low thermal resistance permitting lower junction temperatures at high dissipation levels, says **General Electric Company, Semiconductor Products, Dept. S/A, Syracuse, New York.**

The design has also resulted in a lower collector saturation resistance. The units measure 70 ohms with 98 percent production at less than 150 ohms.

Write in No. 384 on Reader Service Card

PRESSURE REGULATOR *is lightweight, rugged*

The 13000 Series gage pressure regulator is suitable for pressurizing electronic compartments, canopy seals, and reservoirs, as well as for other aircraft uses, says **Aerodyne Controls Corp., Dept. S/A, 1783 New York Ave., Huntington Station, N.Y.** The regulator maintains the desired outlet pressure from 0.2 o 1.0 psi, depending upon the flow, and it is virtually unaffected by variations in supply pressure and altitude.

Performance specifications for one of the compact, rugged devices in the series include a supply air pressure range of zero to 300 psig, and a supply air temperature range of −100 to +300 deg F. Airflow capacity is zero to 4.0 cfm. The unit weights .6 lbs.

Write in No. 385 on Reader Service Card

SILICON CONTROL RECTIFIER *provides ratings to 10 amps*

The C-35 silicon control rectifier is a 3-junction semiconductor device for use in power control and power switching applications requiring blocking voltages up to 400 volts and load currents up to 16 amps, says **General Electric Company, Semi-Conductor Products, Dept. S/A, Syracuse, N.Y.**

The control rectifier reverse characteristic also is similar to a normal silicon rectifier that it represents essentially an open circuit with negative anode to cathode voltage. The forward characteristic is such that it will block positive anode to cathode volts below a critical break-over voltage if no signal was applied to the gate terminal. However, by exceeding the forward breakover voltage or applying appropriate gate signal the device will rapidly switch to conducting state and present the characteristically low forward voltage drop of a single junction silicon rectifier.

Write in No. 386 on Reader Service Card

SHAFT DIGITIZER *features versatility*

Versatility has been designed into a shaft digitizing system that converts the position of micrometer lead screw shafts to a digital code which can be punched on a paper tape, according to **Datex Corp., Dept. S/A, 1307 S. Myrtle Ave., Monrovia, Calif.** The system is selectively capable of recording one, two or three channels of shaft position data and fully expanded it will record three channels of shaft position data and one channel of parameters.

Among system components are a shaft position encoder, control chassis, programer, and control panel. The encoder converts the angular position of the shaft to a discretely coded digital notation of 1000 counts per revolution, and the control chassis will accept the output from a three-, four- or five-decimal digit encoder. Code and format are compatible with a Datatron computer.

Write in No. 387 on Reader Service Card

more on page 262

a name-plate

Reeves
INSTRUMENT CORPORATION

familiar to missile engineers everywhere

FROM R & D labs to launching pads . . . up and down the firing ranges . . . around the world at centers and outposts of global defense . . . as well as in the guidance and control packages of prototype and operational missiles . . . Reeves is the known and respected nameplate of an experienced, PROVEN facility.

Qualified engineers seeking rewarding opportunities in these advanced fields are invited to get in touch with us.

11RV59

Write in No. 159 on Reader Service Card at start of Product Preview Section

CIRCUIT TESTER is rugged

This Igniter Circuit Tester, Model 101-5AF, the latest model in its line, is more rugged. With only 0.005 A output, it measures igniter circuit resistance to an accuracy of 0.05 ohm or better, allowing the user to isolate a fault, which a less accurate instrument cannot do, says **Allegany Instrument Co., Inc., Dept. S/A, 1091 Wills Mountain, Cumberland, Maryland.**

The tester is said to be used primarily in field testing of solid fuel rockets such as Polaris, Terrier, Nike, Talos, and aircraft Jato, etc. It is also valuable in static test facilities as well as in igniter production.

Write in No. 388 on Reader Service Card

POWER SUPPLIES are transistorized

The Models TPC-18A and -19A are airborne, transistorized power supplies for the direct plug-in replacement of D-10A dynamotors for aircraft communications and navigation receivers, says **Southwestern Industrial Electronics Co., Dept. S/A, 10201 Westheimer Rd., P. O. Box 13058, Houston 19, Texas.** A transistor multi-vibrator circuit is used to deliver voltage at high efficiency and the circuitry assures complete reliability as well as protection against overload or short-circuit.

Features include over 80 per cent efficiency, long life, and resistance to shock and vibration. The TPC-18A is designed for 14 vdc at 2.25 amps full load, and the TPC-19A, for 28 vdc at 1.11 amps full load. Output of both units is 250 vdc at 100 ma, and both will operate normally up to 50,000 ft. The 19A, which has a regulation of better than five per cent, withstands transients of over 80 V. Regulation of the 18A is better than ten per cent.

Write in No. 389 on Reader Service Card

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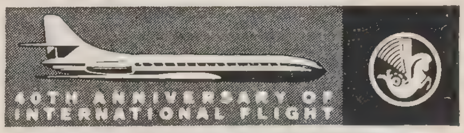
FRENCH FLYING ACE ESTABLISHES FIRST TRANS-AFRICA AIR ROUTE BETWEEN FRANCE—MADAGASCAR!

COMMANDER JEAN DAGNAUX LINKS PARIS, TANANARIVE

Jean Dagnaux

Tananarive, Madagascar, Feb. 10, 1927 – Commander Jean Dagnaux, famous World War flying ace, arrived here today after a daring series of flights from Paris. He piloted his Breguet 19 through Spain, over the Mediterranean, across the Sahara, and down the length of Africa to realize his lifelong ambition – the completion of an overland air route connectin

FIRST IN INTERNATIONAL AIR TRAVEL! The exploits of brave French airmen like Blériot, Bossoutrot, Noguès, Mermoz and Dagnaux have made aviation history since the very beginning of international flight. Air France still follows this great French tradition of leadership in aviation. Today Air France offers the most non-stop flights between New York and Paris and the fastest jet service in Europe and the Middle East aboard sleek, swift Caravelle Jets. Next year Air France plans to cover the world's most extensive route network with one of the world's largest pure-jet fleets, featuring the world's largest, fastest, most luxurious airliner—Air France 707 Intercontinental Jet.

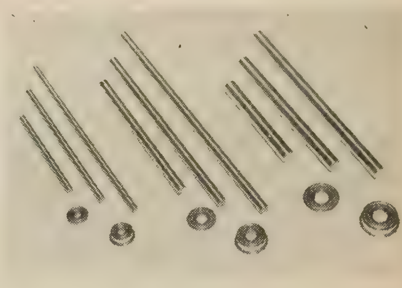


AIR FRANCE

WORLD'S LARGEST AIRLINE / WORLD'S FIRST INTERNATIONAL AIR SERVICE

Write in No. 214 on Reader Service Card at start of Product Preview Section

BALL BEARINGS for ultra-precision



These better than ABEC 7 tolerance type E selected precision ball bearings with bore tolerances selected to +.0000 –.0001, permit better fits and less sloppiness in all precise instrument assembly applications, says **PIC Design Corp., Dept. S/A, 477 Atlantic Ave., E. Rockaway, L. I., N.Y.**

The tolerances are compared with +.0000 –.0002 specified.

Write in No. 390 on Reader Service Card

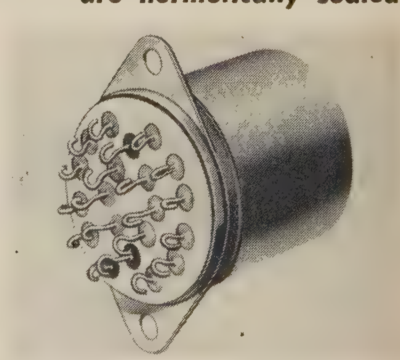
HEATING ELEMENTS braze stainless steel

A furnaceless method for brazing stainless steel honeycomb by flexible high temperature heating elements using a woven wire mesh as the basic conductor has been developed by **Electrofilm Corp., Dept. S/A, No. Hollywood, Calif.** It brazes with less than 8 watts per square inch in about 3 hours using 5 kva heaters in module shapes of 12x52 in.

Blankets tested have withstood 50 cycles from room temperature to 1800 deg F.

Write in No. 391 on Reader Service Card

RELAYS are hermetically sealed



This style 520 relay meets the requirements for a miniature 6 PDT hermetically sealed unit and meets the following MIL specifications and drawing: MIL-R-5757C; MIL-R-25018; MS-24115-6 Class B, type II, grade 3, says **Price Electric Corp., Dept. S/A, Frederick, Md.** General characteristics for 26.5 v operation include contact arrangement of six pole double-throw 6 form C; vibration 15 G to 2000 cps.

Write in No. 392 on Reader Service Card

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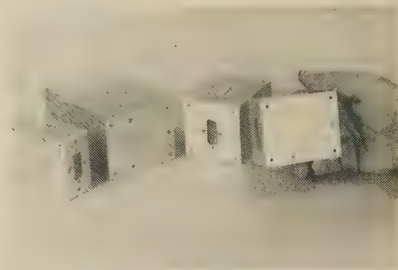
TELEMETERING EQUIPMENT has modular design



The K-series equipment in modular packages is designed for multiplexing and coding data in PDM form in airborne and ground-based data systems. Typical specifications include continuous operation from –55 deg to +100 deg C, 30g's vibration at 5-2000 cps, 200g's shock for 11 millisec and 95 per cent R.H., says **Applied Science Corp. of Princeton, Dept. S/A, P.O. Box 44, Princeton, N.J.**

The current line consists of electronic commutators, mechanical commutators, low-level amplifiers, pulse-width keyers and low-voltage power supplies. The modules have a standard dimension of 3⅛ in. high by 2½ in. wide. The package lengths are available in multiples of ⅝ in.

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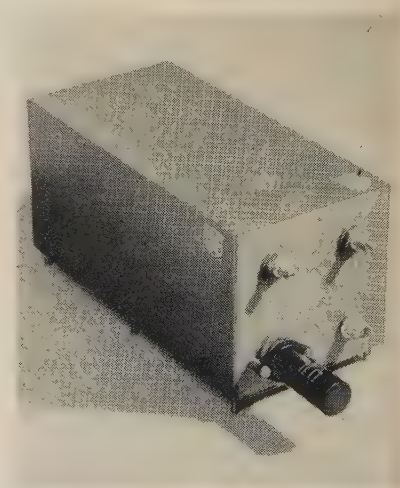
DELAY LINE is dual channel type



The Model 71-05 delay line is a relay-operated, dual-channel type that obtains coincidence between two signals of different time and a third reference signal. The device offers a delay of one to 1.5 usec, and the delay is independently variable in each each channel in 0.05 usec increments, says **ESC Corp., Dept. S/A, 534 Bergen Blvd., Palisades Park, N.J.**

Output rise time is 0.06 usec per channel and impedance is 1000 ohms. The unit measures 8x4x4 in.

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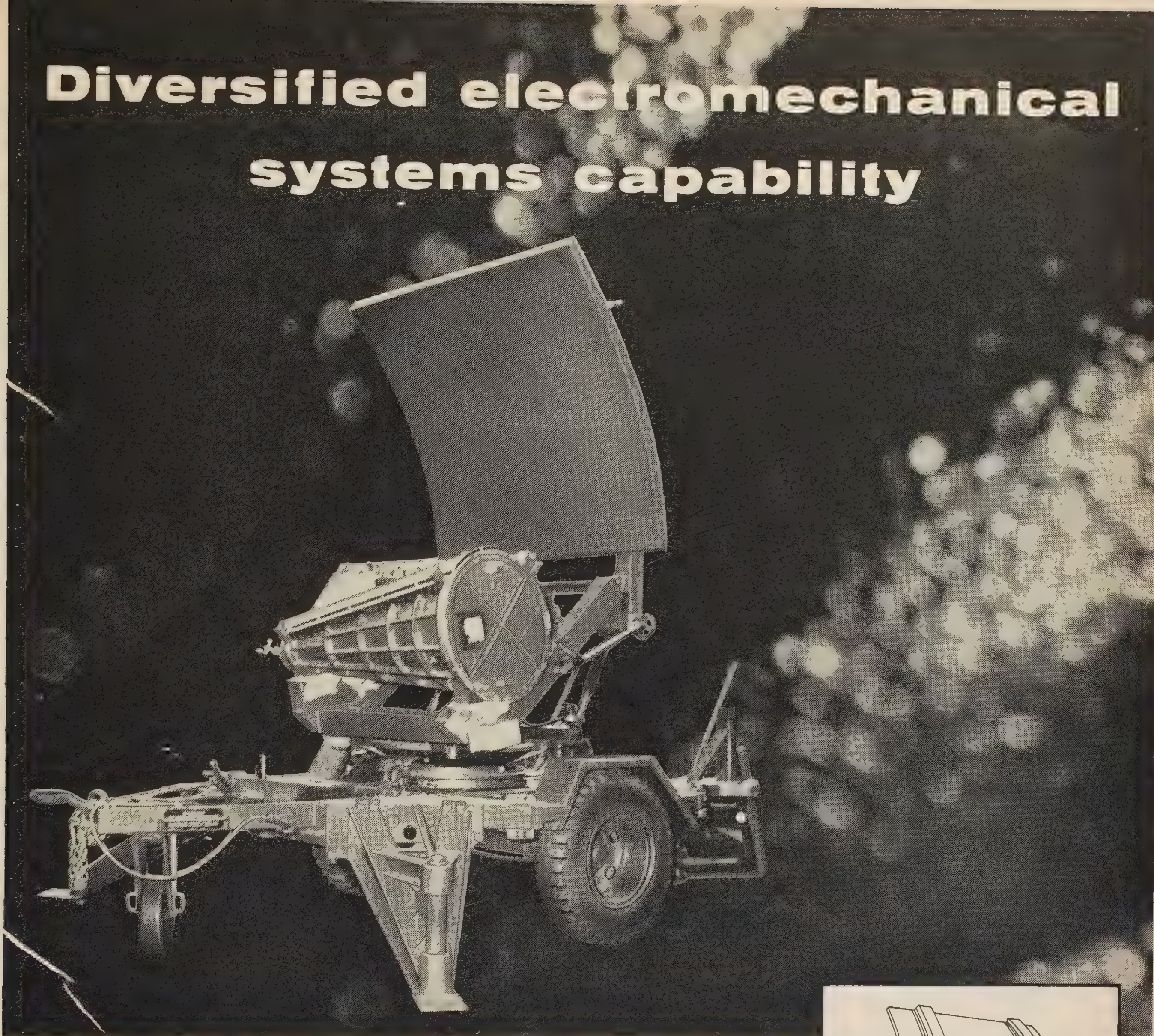
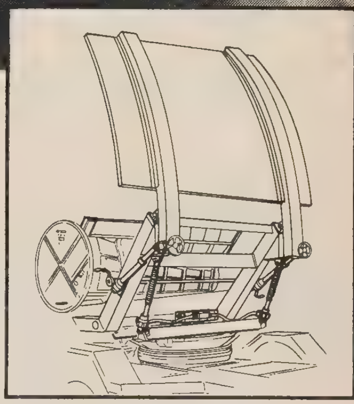
Diversified electromechanical systems capability



AiResearch Actuation Systems For Portable Radar represent a typical electromechanical systems application in ground support equipment. Two types of AiResearch actuation systems are now in production for the Army's mobile trailer-mounted ground radar unit. They consist of a manually operated antenna folding storage system and an electrically powered antenna elevation system.

Designed to operate under the most severe environmental conditions, this type of electromechanical system can operate on 60 cycle A.C., 400 cycle A.C., or 28 volt D.C. Other suggested applications include: *missile launchers, missile ground handling and support equipment, armored vehicle fire control and ballistic handling systems, and mobile communications equipment requiring servoed actuating systems.*

AiResearch leadership in the development and production of electromechanical equipment for aircraft, ground handling, ordnance and missile systems of all types also includes such recent examples as spoiler servo control systems, magnetron and Klystron tuning devices, and safe-arm mechanisms for missile igniting. We invite you to submit a problem statement of your electromechanical requirements.



U.S. Army Signal Corps ground portable radar unit operated with two AiResearch electromechanical actuation systems.

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

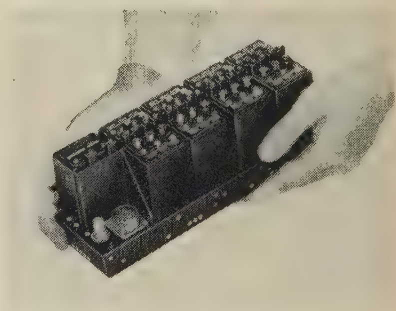
Write in No. 165 on Reader Service Card at start of Product Preview Section

SILICONE GREASE for ferrous units

A silicone grease as a rust inhibitor and lubricant for mated, threaded or non-threaded ferrous components and fabricated rubber parts is available from **General Electric Co.'s Silicone Products Dept., Dept. S/A, Waterford, N.Y.** Designated SS-4007, the compound maintains consistency from –75 deg F to +300 deg F. The product is chemically inert, and protects metals against air oxidation. After 70 hours at 212F in air, no pitting or corrosion occurs on brass, cadmium plated steel, zinc, magnesium, aluminum and steel coated with the silicone grease.

Write in No. 395 on Reader Service Card

TELEMETRY COMPONENTS for small space installation



Type 1405 Mini-Mount is a pre-wired, welded "T" shaped mount designed to accept Type 1213A Subcarrier Oscillators and a Type 1106 A Wideband Amplifier, says **Tele-Dynamics Inc., Dept. S/A, 5000 Parkside Ave., Philadelphia, Pa.**

Sizes are available for 4, 8 and 12 subcarrier channels. The mount attaches directly to the vehicle structure. All test points, trimmers and receptacles are accessible.

Write in No. 396 on Reader Service Card

FERRITE ISOLATOR for K_U band

The Model W-568-3A transverse field isolator consists of rectangular wave guide of permanent magnetic transverse field and ferrite sections built into the unit. Among the more important features is the frequency range of 12.5 to 18 K mcps with isolation at 20 db minimum and insertion loss of only 1.0 db maximum, says **Kearfott Microwave Div., Dept. S/A, 14844 Oxnodge St., Van Nuys, Calif.**

The unit has an input VSWR of 1.14 maximum with a peak power at a 100 kw nominal and a temperature range of from —55 deg C to +150 deg C. Exact size is 3 in deep, 1.8 in high, 2.175 in wide.

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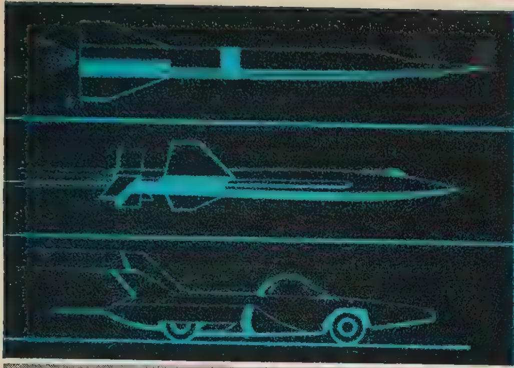
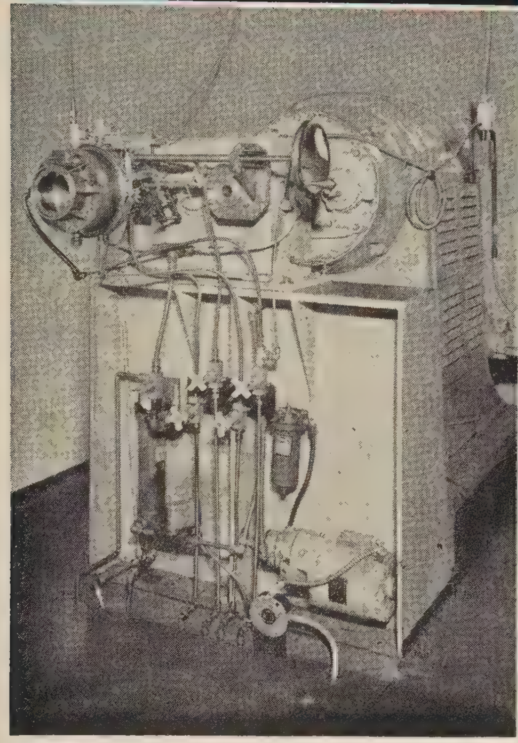
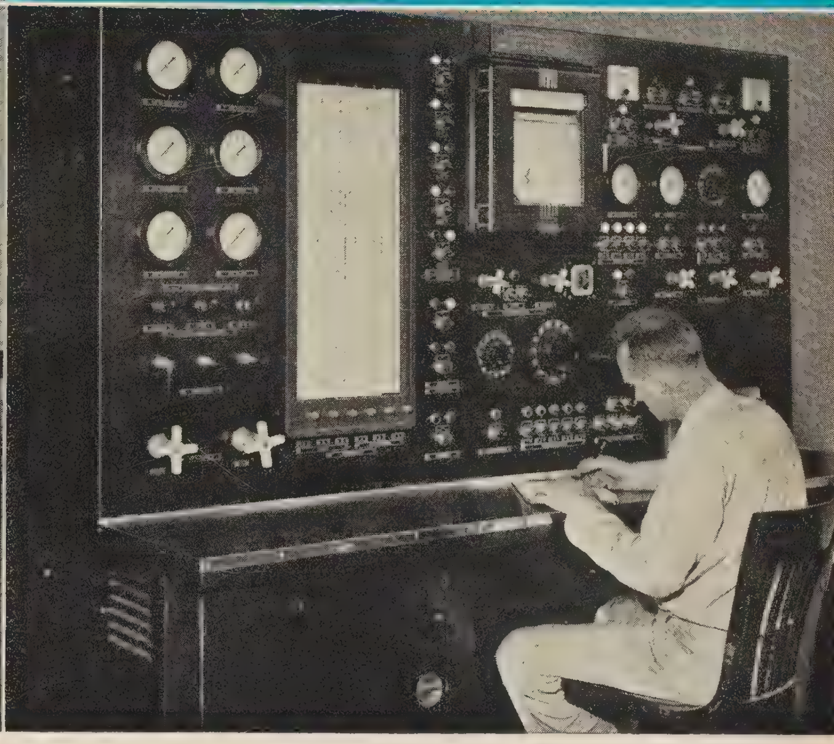


Breakthrough

at 80,000 R.P.M.!





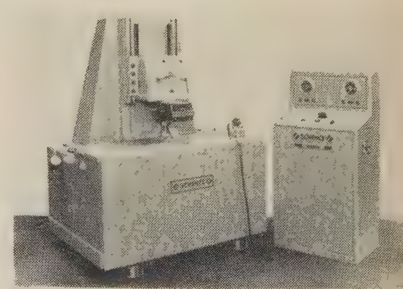
ALUMINUM PLATE is direct chilled

This 921-T-DC aluminum tooling plate, direct chilled during casting, has a fine-grain, uniform molecular structure with greatly improved mechanical properties and machinability, says **Pioneer Aluminum, Inc., Dept. S/A, Los Angeles, Calif.** In the direct chill casting procedure, the molten alloy pours into a water-cooled mold.

With the cooling of all four edges there is instantaneous control of solidification which is said to provide greater density, lower porosity, and higher mechanical properties.

Write in No. 398 on Reader Service Card

FATIGUE TESTER covers wide range



This universal pulsator PUV vertical fatigue testing machine series of 4 sizes covers a load range from 6 to 20 tons and a frequency range (Load cycles) from 600 to 10,000 cyc/min, according to **Cosa Corp., Dept. S/A, 405 Lexington Ave., New York 17, N.Y.** The extremely large stroke of these models enables them to test very soft materials (runner or plastic) with low frequency, and rigid parts (gear wheel connecting rods, steel test bars, etc.) with high frequency.

It also extends application to torsion and bending tests previously requiring special, single-purpose machines.

Write in No. 399 on Reader Service Card

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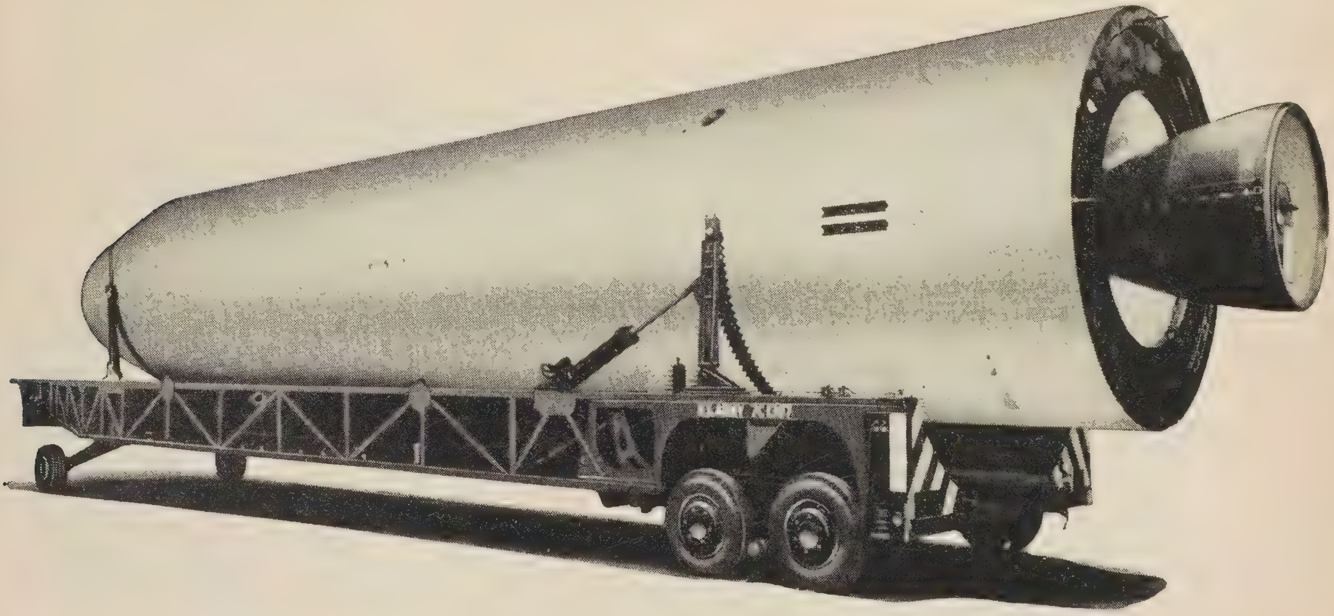
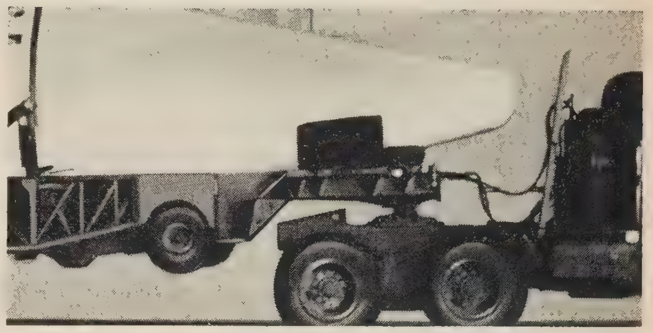
FRUEHAUF IS A DEPENDABLE SOURCE OF **IDEAS AND PRODUCTS** FOR DEFENSE



Most Efficient Supplier of Ground Handling Equipment For Today's Modern Space Age!



From World War II days to our present space age Fruehauf has been an active leader in the research, design, and development of the multitude of rapidly changing ground handling vehicles demanded by the military. Among the most recent of these is the Jupiter Transporter, shown above, which is the result of close teamwork between engineers at Fruehauf and Chrysler Corporation, prime contractor for the Jupiter.

Fruehauf's unsurpassed experience in both commercial and military ground transportation makes them the logical choice when ground handling equipment problems arise. As the world's leading builder of commercial Trailers, Fruehauf has pioneered in the research, design and production of containers or transporters for many types of missiles . . . shelters for mobile radar and electronic equipment . . . specialized Tank-Trailers for standard and exotic fuels . . . powder haul vans . . . mobile containers for materials and supplies . . . as well as over 400 different types of other military vehicles.

At Fruehauf are engineers and designers who have met and solved practically every type of problem in space age ground transportation. You'll find modern, diversified Fruehauf manufacturing plants all across the nation, with automated production lines equipped with advanced, precision machinery.

When your military contract involves ground handling equipment, why don't you consult Fruehauf? No one is better equipped, or more qualified, to help you solve these problems.

MILITARY EQUIPMENT DIVISION

FRUEHAUF TRAILER COMPANY

10942 Harper Avenue, Detroit 32 • 5137 South Boyle Avenue, Los Angeles 58

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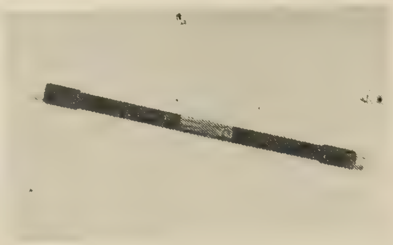
COMPACT FILTER isolates UHF



The low pass filter LP-267 has been designed to isolate UHF from the L-band, according to **Electronic Specialty Co., Dept. S/A, 5121 San Fernando Rd., Los Angeles 39, Calif.** Insertion loss is greater than 100 db between 900 to 1300 mc and under 0.5 db between dc to 400 mc.

Input VSWR in the pass band is 1.4 maximum. The filter, which weighs under five oz and needs only the space of an equivalent length of coax cable, can handle 50 W average power. The device is normally supplied with Type N connectors.

Write in No. 400 on Reader Service Card

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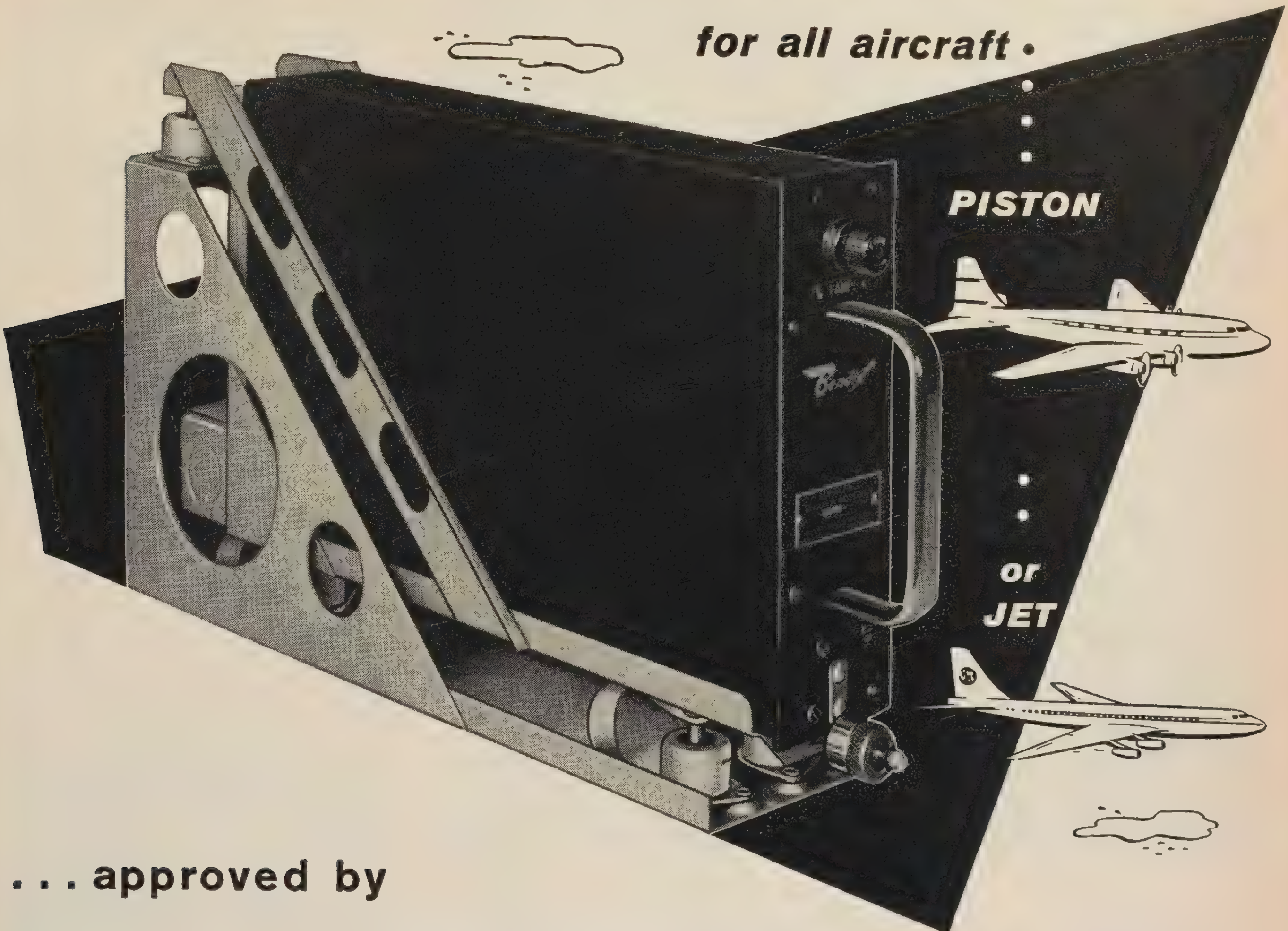
MOUNTING SYSTEMS



. . . approved by
electronic equipment manufacturers for aircraft use

Here's why LORD is your best source for electronic mounting systems:

Complete line of ATR bases for both piston and jet aircraft . . . plus special systems.

Superior performance results from LORD's 35-year background in vibration/shock/noise control. This assures positive protection for radio transmitters and receivers, radar, Doppler, Loran, ILS, antennae, controls and other equipment.

Good delivery is insured by proved designs, qualified components and complete modern facilities for engineering, production and testing.

Why not prove it to yourself? Contact the nearest LORD Field Engineering office or the Home Office, Erie, Pa.

SPECIFY LORD MOUNTING SYSTEMS:

Standard ATR systems for piston aircraft. Available in ¼, ⅜, ½ and full sizes, short and long versions. Meet all applicable specifications including ARINC-404 shock and vibration requirements. Utilize proved Temproof Mountings.

Standard ATR systems for jet aircraft. Available exclusively from Lord with BTR (Broad Temperature Range) elastomeric mountings. Excellent all-attitude control of high-frequency vibration from —65° to + 300°F.

Special mounting systems. Custom designed on complete systems basis to meet specific needs. Integrated bases can be furnished which combine equipment, connectors, components on a common structure. Extensive experience assures system will meet cost and performance goals.

FIELD ENGINEERING OFFICES

ATLANTA, GEORGIA - CEdar 7-9247
BOSTON, MASS. - HAncock 6-9135
CHICAGO, ILL. - MIchigan 2-6010
DALLAS, TEXAS - RIverside 1-3392
DAYTON, OHIO - BAldwin 4-0351
DETROIT, MICH. - DIamond 1-4340
KANSAS CITY, MO. - WEstport 1-0138
LOS ANGELES, CAL. - HOllywood 4-7593
NEW YORK, N. Y. - CIrcle 7-3326
PHILADELPHIA, PA. - PEnnypacker 5-3559
SAN FRANCISCO, CAL. - EXbrook 7-6280
WINTER PARK, FLA. - MIdway 7-5501

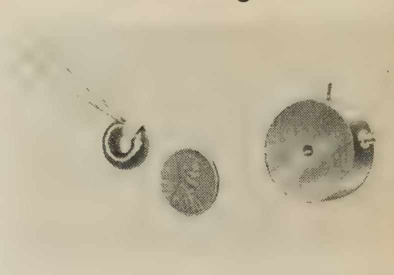
"In Canada—Railway & Power Engineering Corporation Limited"

LORD®

LORD MANUFACTURING COMPANY • ERIE, PA.

Write in No. 171 on Reader Service Card at start of Product Preview Section

TOROID INDUCTORS have high Q factor

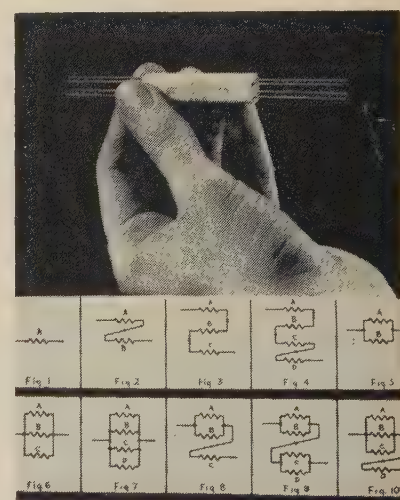


Series KT, toroid inductors, have high Q factor, excellent stability vs. temperature and current and self-shielding effects, says **Kelvin Electric Co., Dept. S/A, 5907 Noble Ave, Van Nuys, Calif.**

Coils are available in 3 forms: uncased, with protective wax coating; hermetically sealed in steel cases to MIL-T-27A specifications, and encapsulated in high temperature plastic. Temperature range from −55 deg C to +125 deg C.

Write in No. 403 on Reader Service Card

RESISTORS for development work



These multi-range resistors permit delivery of 200 fixed resistance values from five basic units to provide engineers with a time-saving, flexible, low cost research, development and prototype tool, says **International Resistance Co., Dept. S/A, 401 N. Broad St., Philadelphia 8, Pa.** Each multi-range resistor contains four component ten-W, wire-wound resistors in a common steatite housing.

The components are of two or four different values, and each has its own pair of axial leads. Up to 47 values are available through connection of the leads in various series, parallel and series-parallel arrangements. Units are available in ranges of 0.5 to 15,000 ohms, and 3000 to 50,000 ohms.

Write in No. 404 on Reader Service Card

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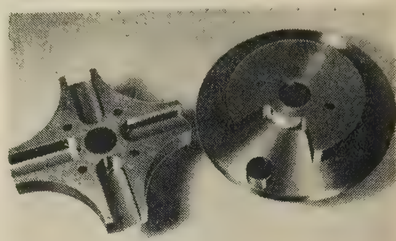
DRIVES for automation units



These drives have 3 to 24 indexing stations for shaft center distances from 3 to 6 in in ¼ in increments, and a wide variety of hub and bore diameters. They are said to meet demands of high speed automation in industry, says **Genevamatic Engineering Corp., Dept. S/A, P. O. Box 10386, Tampa 9, Fla.** Center distances less than, intermediate, or greater than the standard 3-6 in range are available.

Write in No. 405 on Reader Service Card

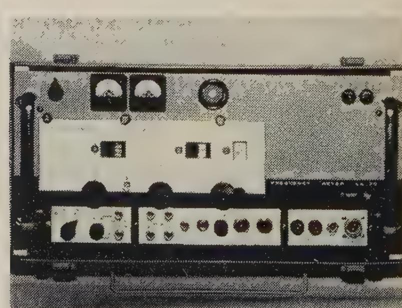
METALLIZING UNIT has vacuum chamber

A bell-jar metallizing unit, model 3144, intended for developmental work or limited volume deposition of one or more materials under vacuum can be used for production, research and development of such products as improved semi-conductors, precision resistors and capacitors, according to **NRC Equipment Corp., Dept. S/A, Newton 61, Mass.** All elements, including the power supply and vibration-isolated pumping system are contained in a 3x4 ft enameled steel cabinet.

The vacuum chamber is formed by a 30½ high bell-jar and a 28 in diameter precision ground baseplate.

Write in No. 406 on Reader Service Card

FREQUENCY METER for very-high frequencies



A redesigned version of Model LA-70 VHF Frequency Meter has a frequency range from 10 kcps to 3000 mcps, says **Lavoie Labs. Inc., Dept. S/A, Marganville, N.J.** The unit is accurate to 1 ppm from 20 mcps to 3000 mcps and reaches full accuracy with only a 20 min warmup.

Write in No. 407 on Reader Service Card

more on page 278

SINGLE-SIDE-BAND FILTERS have high bandwidth ratios

Ranging from 10 to 500 kc, these crystal filters are manufactured to exceed a wide variety of electrical, mechanical, and environmental specifications. The filters obtain unusually high bandwidith ratios and excellent shape factors, says **Bulova Watch Co., Electronics Div., Dept. S/A, Woodside 77, N.Y.**

With a 85 kc carrier, the 3 db bandwidth is 3.4 kc and the attenuation is over 40 db. Using a more complex design a 60 db attenuation can be achieved. The dimensions of the unit are 5 in x 2 in x 2 in. Bandwidth ratios of better than 10 percent may be reacched with side band crystal filters ranging from 60 to 200 kcps.

Write in No. 408 on Reader Service Card

SERVO AMPLIFIER has high voltage gain

Instantaneous operation is provided by this rugged, transistorized, six-W, 400-cycle servo amplifier, says **Belock Instrument Corp., Dept. S/A, 112-03 14th Ave., College Point, N.Y.** It occupies a space of nine cu in and plugs into a standard octal type socket.

Voltage gain is greater than 4500, and the tiny unit has an input impedance of greater than 70,000 ohms at 27 deg C. A variable gain control is included.

Write in No. 409 on Reader Service Card

DELAY LINES offer minimum attenuation

These ultrasonic delay lines are available with very short and extremely long delay time and will store a signal with minimum attenuation for periods ranging from less than 50 to more than 15000 usec, says **Corning Glass Works, Dept. S/A, Corning, N.Y.**

These very-long delay lines were developed through improvements in fused silican production methods. The low acoustic attenuation of fused silica makes possible delay times of 15000 usec in a single plane delay line.

Write in No. 410 on Reader Service Card

RADAR TEST SET shows versatility

Facilities of this 200-mc radar test set include provisions for day-to-day pulse envelope comparison, spectrum analysis, crystal and variable markers, delayed pulse or CW signal ouput, and others, says **Marconi Instruments, Dept. S/A, 111 Cedar Lane, Englewood, N.J.** When it is used in conjunction with the Marconi 1000 W RF absorption power meter, it permits complete radar checkout without signal radiation.

Both test set and power meter are built to military specifications, including requirements for vibration and humidity.

Write in No. 411 on Reader Service Card

WIRE INSULATION withstands high heat

A temperature rating of 1000 deg F for continuous operation is reported for Durock, a flexible, ceramic wire insulation announced by **Packard-Bell Electronics Corp., Dept. S/A, 389 N. Fair Oaks Ave., Pasadena, Calif.** A thickness of 0.6 mils of the ceramic provides a resistivity of 400 V dc.

Completely boron and cobalt-free, the material has a barns cross-section capture of under 20. Durock has been coated on wire from ten mils up, and aluminum, nickel-clad copper, and Constantan are among the metals available as conductors.

Write in No. 412 on Reader Service Card

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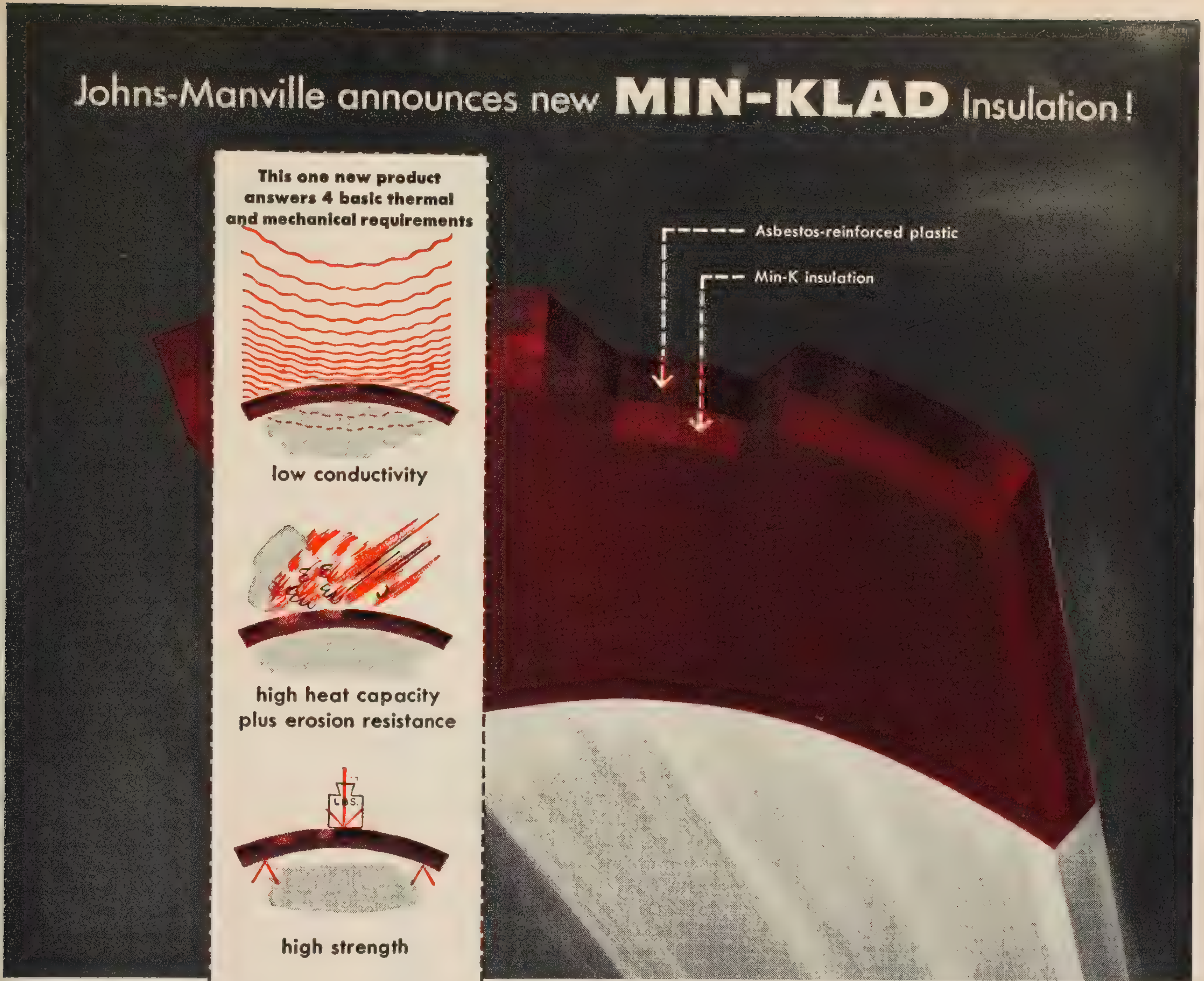


New Min-Klad insulation is engineered and molded to your design requirements.

Combines the capabilities of asbestos-reinforced plastic with the dramatically low conductivity of MIN-K insulation!

New Min-Klad insulation may well be the most significant advance ever made in missile and rocket insulation.

Developed by Johns-Manville research scientists, Min-Klad is the only product of its kind, a permanent lamination of the missile industry's two most effective high-temperature materials: 1) reinforced plastic and 2) J-M's recently developed Min-K insulation.

Does more than plastic alone

Min-Klad gives the missile designer all the advantages of high-temperature plastic: Strength, toughness, rigidity! Erosion resistance! High heat capacity! Yet Min-Klad does more.

It also insulates . . . and with dramatic effectiveness! Its insulating element is J-M's Min-K, an insulation with thermal conductivity that is actually lower than the molecular conductivity of still air. And this conductivity (already less than half that of the best fibrous insulations) drops still further with altitude. At 10 miles, for example, it is decreased by as much as 40%, with further decreases at greater altitudes.

Wide range of applications

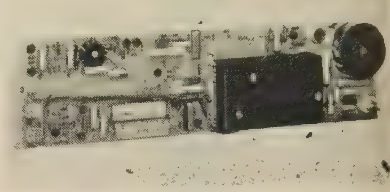
Min-Klad offers the missile and rocket designer a rich choice of heat-control possibilities. It may be used for a part that must insulate, yet have the structural advantages of plastic. Where requirements call for a scuff- and erosion-resistant insulating surface . . . or for a good adhesive bond between Min-K insulation and other surfaces. Or, it may be used to control high transient temperatures! For high heat capacity of asbestos-reinforced plastic combined with the low conductivity and heat capacity of Min-K result in a product that provides minimum heat transfer under transient conditions.

Min-Klad is now being tested for approximately two dozen missile and rocket designs. Why not investigate this new material for your present thermal requirements? Upon request, we'll be pleased to send you a sample of the material along with detailed technical information. Write Johns-Manville, Box 14, New York 16, New York. (Ask, too, for information on Min-K insulation and the new aviation insulation brochure IN-185A.) In Canada: Port Credit, Ontario.

JOHNS-MANVILLE JOHNS-MANVILLE JM PRODUCTS

Write in No. 269 on Reader Service Card at Start of Product Preview Section

SAMPLE AND HOLD SYSTEM for conversion to digital form



This solid-state high-spped Sample and Hold system samples a small segment (less than 1 usec) of an incoming voltage and holds the result for conversion to digital form or for other purposes, says **Packard Bell Computer Corp., Dept. S/A, 1905 S. Cermacost Ave., Los Angeles, Calif.**

The system is constructed on a single-etched board, is self-powered, completely transistorized, has no moving parts, and d-c stabilization is provided by a silicon transistor chopper.

Write in No. 413 on Reader Service Card

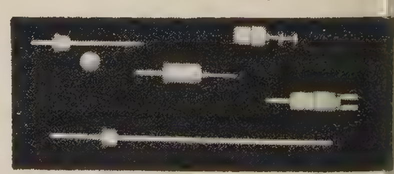
SIZE 8 TRANSFORMER has high impedance levels

Impedance levels comparable to those found in Size 10 and 11 synchros have been achieved in a Size 8 control transformer, according to **Clifton Precision Products Co., Dept. S/A, 9014 W. Chester Pike, Upper Darby, Pa.** Impedances of the 400-cycle CTC-8-A-6 are: Zro=262 /72.2°; Zso=465 /75°; and Zrss= 970 /17°.

The device is a standard 11.8 input control transformer and power input is as low as .058 W.

Write in No. 414 on Reader Service Card

TERMINALS have rivet-type action



These space-saving Teflon-insulated terminals are installed in an electronic chassis by pressing into pre-punched or pre-drilled holes. The Teflon material of insulator tends to relieve its own stress and causes a rivet-type action which anchors and seals, says **Cannon Electric Co., Dept. S/A, 3208 Humboldt St., Los Angeles 31, Calif.** No nut, washer, staking, or soldering is required.

Voltage ratings at sea level range from 2380 V to 4250 V. Standard pin material is silver-plated brass. Available lengths range from 0.1 in to 2.500 in, standard pin diameters from 0.040 in to 0.78 in.

Write in No. 415 on Reader Service Card

more on page 2

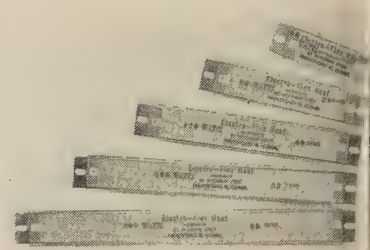
SERVO VALVE is very accurate

This rugged electro-hydraulic servo valve provides the accurate flow modulation required for fast and precise closed loop control of position velocity and acceleration. It is compatible with all present-day program control methods, says **Vickers Inc. Dept. S/A, Waterbury 20, Conn.**

A variable fulcrum of mechanical feedback linkage provides optimum operating flexibility. Extreme reliability and simplicity, it is said, result from two-stage spool construction with only four moving parts. Valve is rated at ten gpm maximum flow at 1,000 psi (assuming ⅓ pressur drop across valve) and operates on supply pressure from 300 to 3,000 psi.

Write in No. 416 on Reader Service Card

POWER RESISTORS are light-weight



These light-weight and space-savi power resistors are designed to mounted in direct contact with chassis. Electrical insulation is silic rubber which is operable continuou at 450 deg F, says **Electro Flex He Inc., Dept. S/A, 83 Woodbine Hartford 6, Conn.**

The units are available in pow ratings of 40, 80, 120, 160 and 2 watts. The 200 watt resistor wei approximately 0.080 lb. Connect tabs are silver-plated brass.

Write in No. 417 on Reader Service C

LEAKLESS VAL is propellant-actuat

A new propellant-actuated va that houses a laterally moving sp and the explosive driving cell been designed with a blind-end i fitting to eliminate pre-actuation le age, says **Beckman & Whitley, I Dept. S/A, 985 E. San Carlos A San Carlos, Calif.** Actuation res in shearing off the blind end to mit fluid to flow past a recess in spool and to the outlet port.

The normally closed valve ha counterbore in the spool to metal particles. An O-ring sys traps the expended combustion g to prevent contamination of the w ing fluid. A simple reload kit mits re-use in system test and ch out or emergency applications.

Write in No. 418 on Reader Servic

more on page

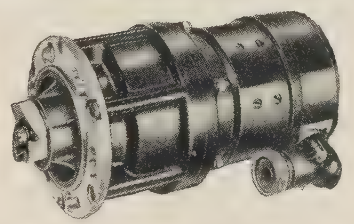
J&H helps the Caribou* climb out of rough fields and short runways

DeHavilland's Caribou cargo and personnel transport is designed for use under less-than-ideal field conditions . . . answering many needs in both military and commercial aviation. These special flying requirements demand rugged, precision equipment that does not impose weight and space penalties. DeHavilland chose J&H components because they fulfilled requirements exactly and were in the production stage—proven and ready to fly.

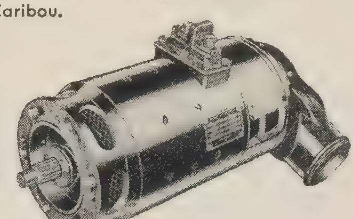
Jack & Heintz can satisfy your system and component needs, no matter how specialized, with aviation's most extensive lineup of electric power systems and components.

Write to: Jack & Heintz, Inc., 17634 Broadway, Cleveland 1, Ohio.

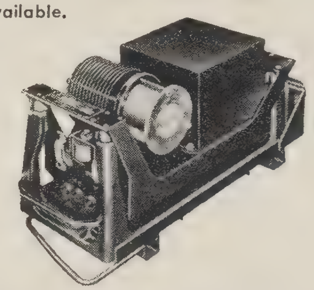
**Both military and commercial versions.*



JH6BFSR3 Starter's d-c motor has excellent torque characteristics. This, together with machine's rugged clutch and convenient button-hole mounting, made it ideal for the Caribou.



G300-4B Generator selected for its superior low-speed operating characteristics. Starter-generator versions of this machine are also available.



GC34-2 Control Panel selected for compactness, and convenient installation and maintenance. Versions of this panel serve starter-generator applications.

JACK & HEINTZ, Inc.

SYSTEMS FOR AIRCRAFT, MISSILES AND GROUND SUPPORT

Write in No. 181 on Reader Service Card at start of Product Preview Section

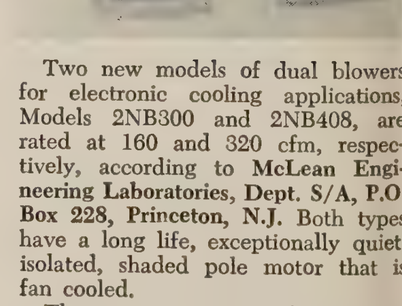
REFUELING NOZZLES have 600-gpm rating

Models P-2750 and P-2751 are underwing, single point nozzles designed to meet refueling requirements of 600 gpm at a seven-psi pressure drop across the nozzle, says **Controls Co. of America, Dept. S/A, Milwaukee, Wisc.** A manually controlled lever prevents opening of the poppet valve until these lightweight, rugged nozzles are fully engaged, and it is not necessary to disengage the nozzles to shut off fuel flow.

Model P-2751 has a straight inlet; and Model P-2750 a 45-deg angle inlet; both units have bicycle grip or ring-type handles.

Write in No. 419 on Reader Service Card

COOLING UNITS are dual blower types



Two new models of dual blowers for electronic cooling applications, Models 2NB300 and 2NB408, are rated at 160 and 320 cfm, respectively, according to **McLean Engineering Laboratories, Dept. S/A, P.O. Box 228, Princeton, N.J.** Both types have a long life, exceptionally quiet, isolated, shaded pole motor that is fan cooled.

The motor meets Specification CC-M-636A. Blowers feature a stainless steel shaft, are fungus protected, and moisture and corrosion resistant. The standard unit has a 115-V, 60-cycle rating.

Write in No. 420 on Reader Service Card

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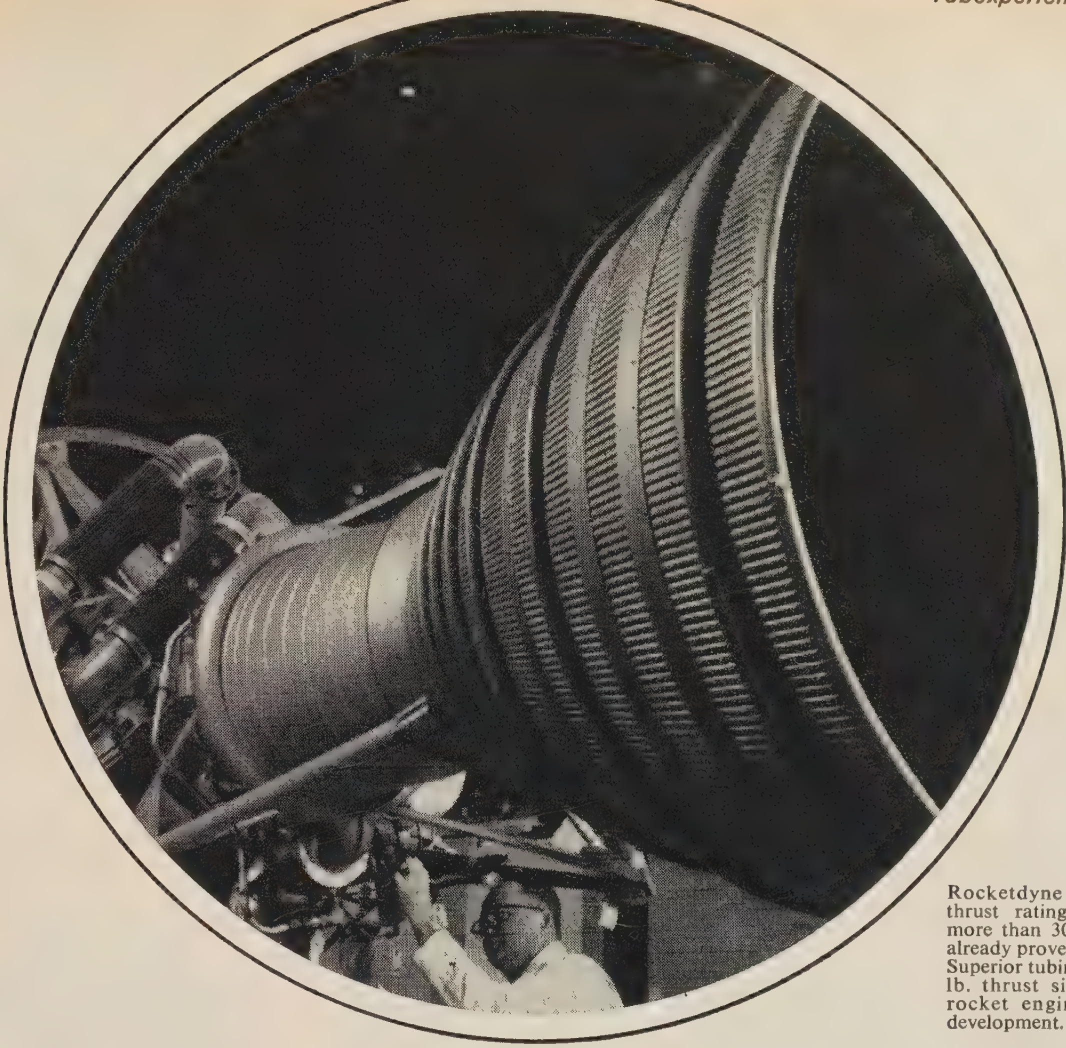

Rocketdyne engines with thrust ratings of 5000 to more than 300,000 lb. have already proved the quality of Superior tubing. A 1,500,000 lb. thrust single chamber rocket engine is now in development.

Superior Thin-Wall Nickel Tubing Survives Rigors of Preparation for Outer Space

Thrust chambers of the Rocketdyne engines that propel the Atlas, Thor and Jupiter missiles into outer space are composed of over 200 pieces of formed and shaped Superior Grade "A" nickel tubing. Tubing must meet rigid design requirements and be amenable to exacting and intricate forming and fabrication. Finished parts are subjected to tests that must insure reliability. Typical of the unusually severe fabrication, test and operational conditions it must survive are the following.

- Die-press operations which develop pressure of 600 psi in the press and up to 20,000 psi in the tube while forming cross-section shapes varying from round to rectangular to octagonal.

- Brazing operations which subject the tube to as many as 15 heating and cooling cycles at approximately 1200°F.

- Test firings far in excess of required tactical maximum in which the only material between the coolant in the tubes and the combustion gases (at approximately 5000°F and high pressures) is the very thin wall of tubing.

Only the highest quality tubing, produced and fabricated with master skills, is good enough for the thrust chambers in which Superior tubing serves. That is why Rocketdyne Division, North American Aviation, Inc., depends on Superior for much of its tubing needs.

Superior's experience in the nuclear and missile tubing field is extensive. More than 120 analyses in a wide range of ID, OD and wall thicknesses are now available. They are described in Bulletin 41. Write for a copy today. Superior Tube Company, 2038 Germantown Ave., Norristown, Pa.

"A" Nickel is a registered trademark of International Nickel Co.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

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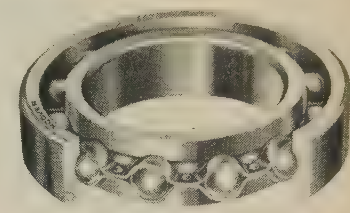
BALL BEARINGS *are light weight*

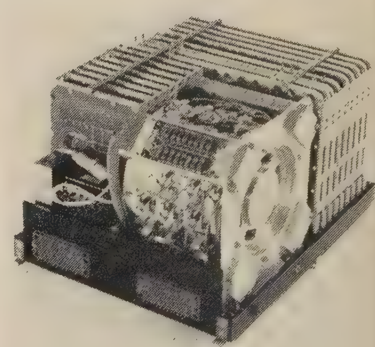


These 3L00 extra light ball bearings are smaller than standard bearings of comparable shaft sizes and are recommended for applications requiring maximum shaft diameters and minimum housing areas, says **Hoover Ball and Bearing Co., Dept. S/A, 5400 S. State Road, Ann Arbor, Mich.** Styles include open, single or double shield, or single or double contact seal, and combination contact seal and shield.

All are available with or without snap ring.

Write in No. 379 on Reader Service Card

DIGITAL COMPUTER *for airborne use*



Most navigational problems in both aircraft and missiles can be accurately solved by this small, silicon-transistorized multi-functional airborne digital computer, says **Librascope, Inc., Dept. S/A, Glendale, Calif.** The AN/ASN-24 can also be used for missile guidance functions.

The computer design is reported to give the device the ability to accept inputs from new navigational aids as they are developed. The two-address, serial, binary data computer stores digital impulses as 25-bit words on a 6000 rpm memory drum. Total storage is 2048 words. The computer handles data from TACAN, celestial, inertial and Doppler information, radio, true airspeed systems and heading instruments. Computer errors are under 0.1 per cent, and the device weighs 32 lbs and requires 0.55 cu ft of space.

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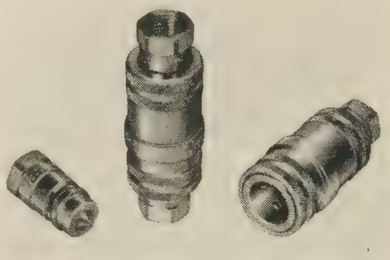
COUPLER CONNECTOR for use under pressure

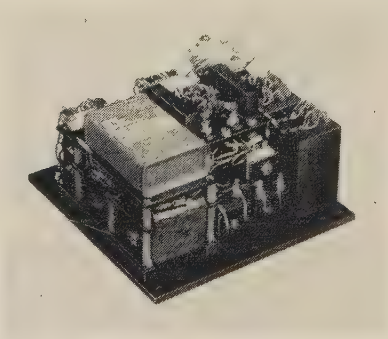


This SP-500 quick-disconnect coupler enables the user to connect or disconnect hydraulic lines at full operating pressure, without sacrificing automatic break-away characteristics. F characteristics are excellent and valve and seal action are said to be positive by **The Bruning Co., Dept. S/A, Lincoln, Neb.** It handles a broad range of fluid mediums and has wide operating temperature range, from −40° to +250° F., and operating pressures exceed 7500 psi.

The coupler has full swivel action; absorbs torsional strains and stresses from adjacent components; eliminates need for swivel adapters, it is stated.

Write in No. 424 on Reader Service Card

POWER INVERTER is solid state type



A combination of transistor and magnetic amplifier circuitry in this static power inverter is used to convert a 26 to 30-V dc source to a 115-V, 400-cycle, single-phase ac source. The solid state device, designed for a stable output of 250 va, is suited to use in missiles, missile checkout systems, aircraft and ground equipment, telemetry, and automation, says **Magnetic Amplifiers, Inc., Dept. S/A, 632 Tinton Ave., New York 55, N.Y.**

Life expectancy is 20,000 hrs and the inverter has no moving parts. Output voltage is adjustable to plus or minus five per cent, and regulation is 1½ per cent for load variations from no-load to full-load. Maximum distortion is five per cent. The inverter can withstand vibrations of ten to 2000 cps and shock to 30 times its 12½-lb weight.

Write in No. 425 on Reader Service Card

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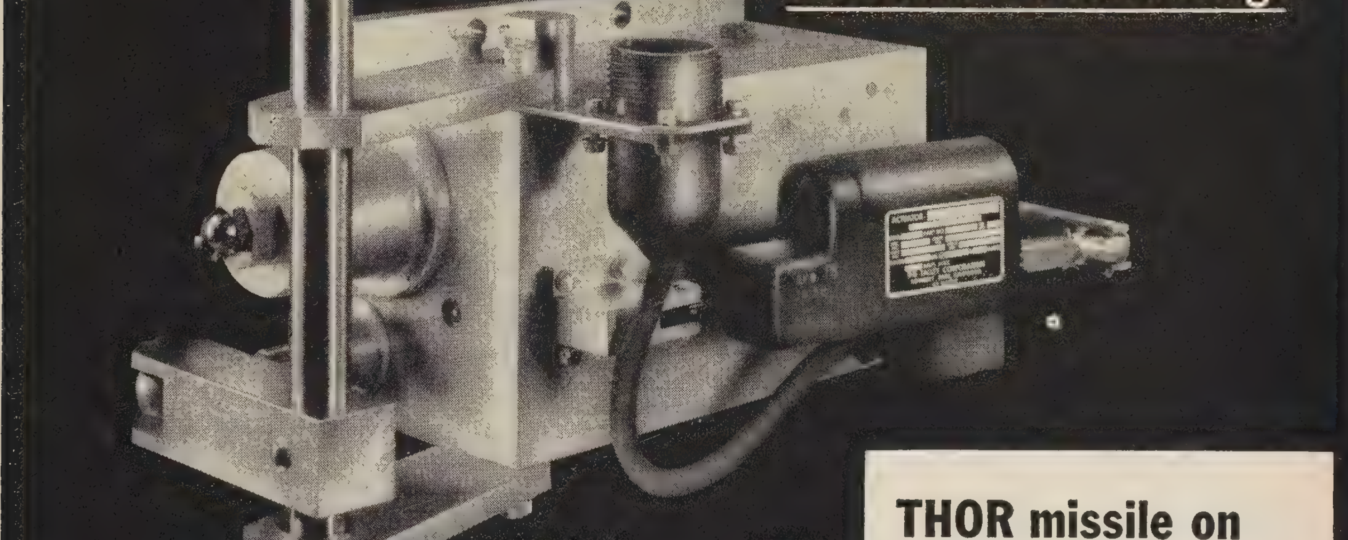
NEW VICKERS® Packaged Valve Assembly accelerates – decelerates Thor Missile Erector smoothly without ratcheting.



Operating Pressure	3400 P.S.I.
Proof Pressure	4500 P.S.I.
Burst Pressure	7500 P.S.I.
Temperature Operating Range	−65°F to +150°F
Filtration Nominal	10 Micron

Smooth control of the Thor erecting cylinder is accomplished by a new Vickers' packaged valve assembly. This assembly provides regulated acceleration-deceleration throughout the erecting cycle without compounding structural vibrations. Despite varying external loads and temperatures, firm positive control is maintained as the missile's center of gravity passes over the pivot point.

This "system engineered" valve is another example of the special ability of the Vickers Marine and Ordnance Department to solve difficult ground support problems. An integrated package, this new valve consists of a metering-type, modulating flow control that is pressure compensated for a fixed pressure differential. An integral, motor-actuated, 4-way directional control regulates starts and stops in mid-cycle.

Now in production, this valve can be used to control a broad range of accelerations, decelerations and overrunning loads merely by varying combinations of orifice sizes and spool configurations. Horsepower input can be adjusted to meet onsite power availability. Valve output can be controlled electrically, mechanically or hydraulically. Mounting flexibility permits valve installation directly on the hydraulic cylinder.

All units are factory pre-tested, interchangeable and require no external lines except to pump and tank. They are built to meet the most demanding reliability requirements.

THOR missile on launch base...

- complete system designed and developed by Douglas Aircraft Company, Inc.
- transporter-erector, launching base and power trailer designed and built by Food Machinery and Chemical Corporation.

- erector and mast control valves, hydraulic power unit, test and checkout stands designed and built by Vickers Incorporated.

If this valve offers a solution to your problems, call Waterbury, Connecticut, PLaza 6-3684 (TWX: WBY 160) for more complete information. Write for a free copy of Bulletin 5303 "Vickers Oil Hydraulics for Missile Systems."

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DIVISION OF SPERRY RAND CORPORATION
Marine and Ordnance Department
WATERBURY 20, CONNECTICUT

Hydraulic Products for Marine and Ground Defense Applications

MO-219

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Write in No. 189 on Reader Service Card at start of Product Preview Section

A-C NETWORK ANALYZER is miniaturized

Model 307, miniaturized A-C Network Analyzer, is comprised of a 10-KC stabilized oscillator driving 4-amplifiers which simulate the generating stations. A single panel type indicating instrument isolated by electronic amplifiers measures power, voltages, currents, and vars, says **General Electric Computer, Dept. S/A, Phoenix, Ariz.**

Line, load, and shunt capacity units are connected by patch cards to represent the network configurations under study. Standards of resistance, capacity and inductance are provided for calibrating the network constants.

Write in No. 426 on Reader Service Card

ROTARY RELAYS are miniature

The VG series relays are rated at 5 amp for 100,000 operations and can carry 10 amp for 25,000 operations and 15 amp for 2,500 operations, says **Elgin National Watch Co., Electronics Div., Dept. S/A, 2435 No. Naomi St., Burbank, Calif.**

The units measure only ⅞ sq in and weigh 1.5 oz. They operate under vibration of 15 g's from 55 to 2000 cps. with a shock rating of 100 g's. The temperature range extends from −65 deg C to +125 deg C.

Write in No. 427 on Reader Service Card

K-BAND MAGNETRON for missile application

This fixed frequency K-band magnetron M4154 delivers a minimum peak power output of 20 Kw and can withstand a 30 g vibration test from 20 to 2000 cycles, says **Sylvania Electric Products Inc., Dept. S/A, 1740 Broadway, New York 19, N.Y.**

In addition to these K-band magnetrons other types of K-band applications are available such as backward wave magnetrons (carcilnotrons) for the L- S- and X-band frequencies.

Write in No. 428 on Reader Service Card

AUXILIARY POWER for missiles

An auxiliary power unit that will supply electric and hydraulic power to operate a missile's guidance and control systems eliminates external plumbing and is said to cut the number of valves in half. Designed to operate on ethylene oxide, it may also be used with hydrazine. With minor modifications a solid propellant can be used, according to **The Garrett Corp., Dept. S/A, 9851 Sepulveda Blvd., Los Angeles 45, Calif.** It supplies 5 hp for a duration of 7½ minutes at specific load schedule.

Its altitude range is from sea level to more than 100,000 feet.

Write in No. 429 on Reader Service Card

PRESSURE REGULATOR for missile use

This high pressure regulator was designed for the Redstone and Jupiter missiles. Recent tests indicate that the inlet pressure range band can be substantially enlarged and still maintain the close control of outlet pressure in a single stage of regulation, according to **Serodyne Controls Corp., Dept. S/A, 1783 New York Ave., Huntington Station, N.Y.** It is said to be compatible with most of the gases currently used in the aircraft and missile fields.

It will provide simplification of systems using a high-pressure source.

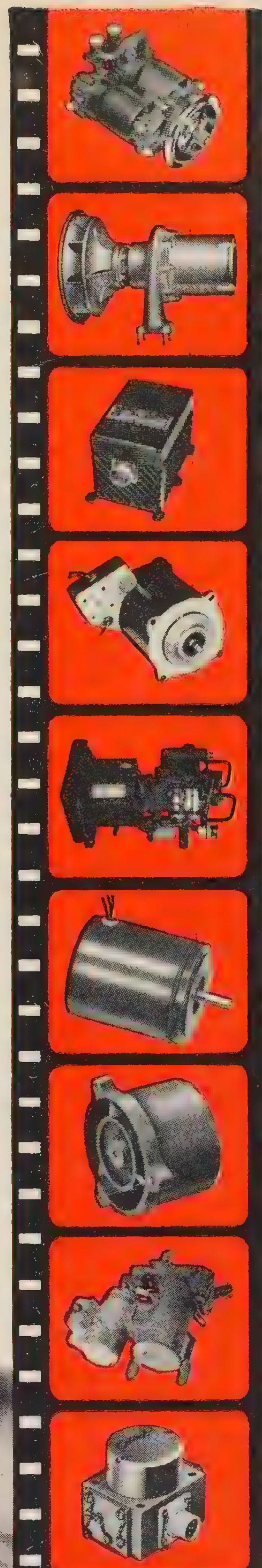
Write in No. 430 on Reader Service Card

more on page 292

COUNTDOWN at PESCO

The "Countdown at Pesco" begins in laboratories far from the launching pads. It begins with teams of resourceful Pesco engineers . . . men of vision eminently qualified to meet the technical challenges and rigid reliability requirements of the aerospace industry. All Pesco products shown at right are now critical components of operational air weapon systems. These components are the products of Pesco's advanced engineering that anticipates the sophisticated requirements of the industry . . . plus Pesco's proven capacity for precision production to meet customer delivery schedules. Investigate Pesco's capabilities before you specify on your next project.

PESCO PRODUCTS DIVISION
BORG-WARNER CORPORATION
24700 North Miles Road • Bedford, Ohio
EXPORT SALES: Borg-Warner International Corporation
36 Wabash Avenue, Chicago 3, Illinois



9 HYDRAULIC PUMPS & PUMP/MOTORS

8 CRYOGENIC PUMPS

7 STATIC INVERTERS

6 ALTERNATORS

5 COOLING PACKAGES

4 ELECTRIC MOTORS

3 AXIAL FLOW FANS

2 HYDRAULIC POWER PACKAGES

1 SERVO VALVES

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This new 20-minute full color film enables you to evaluate firsthand Pesco's research, development and production capabilities.

Contact your nearest Pesco Sales Office or write direct for private showing.

8700-PC

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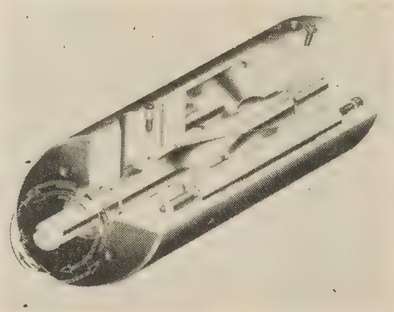
ROTARY ACTUATOR *has high torque*

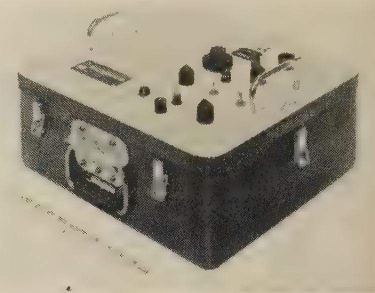


This rotary torque actuator incorporates full cushioning in providing 0 deg to 370 deg of high torque rotation. Powered by air, gas, water or oil, it seals dead tight and will not back off under tension, shock, vibration, or complete power failure, says **Carter Controls, Inc., Dept. S/A, 2818 Bernice Rd., Lansing, Ill.** It may be stopped at any point in the rotation cycle.

Standard cycles are: 0 deg to 100 deg (providing a full 90 deg rotation with the five deg of over travel); 0 deg-190 deg (providing a full 180 deg); 0 deg-280 deg (full 270 deg) and 0 deg-370 deg (full 360 deg).

Write in No. 431 on Reader Service Card

PORTABLE SYSTEM *checks control beacons*



Aircraft air control beacons may be checked out by either radiation or umbilical test methods with the ATC Transponder Ramp Tester, a 35-lb ac or battery-operated system, says **Packard Bell Electronics Corp., Dept. S/A, 12333 W. Olympic Blvd., Los Angeles 64, Calif.** The self-contained device evaluates interrogator-response characteristics of the beacon system and provides a go/no go direct readout.

The device has a rechargeable battery with a built-in trickler charge. It features tight, water-proof construction and is designed for simple operation and maintenance.

Write in No. 432 on Reader Service Card

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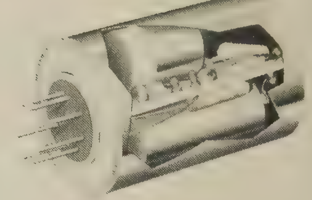
VOLTAGE REFERENCE offers cell stability

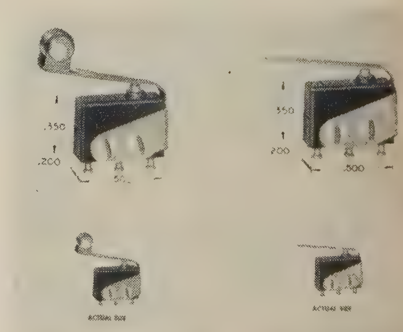


Outstanding stability over wide variations in input and environment is provided by a voltage reference with a one-V dc output operating into 1000 ohms, says **Networks Electronic Corp., Dept. S/A, 14806 Oxnard St., Van Nuys, Calif.** Output is held to ±1.2 mv over inputs from 100 to 130 V ac and frequencies from 25 to 10,000 cps.

The device may be used as a reference voltage source in power supplies, metering circuits and strip chart recorders. Temperature range for the stability rating is −55 to +100 deg C, or any combination of specified variations in temperature and power input. The unit weighs three oz, is 1.75 in long and 1.35 in in dia, mounts in any position, and can be plugged into a seven-pin miniature tube socket. Power required is three va nominal.

Write in No. 433 on Reader Service Card

ACTUATORS for very small switches

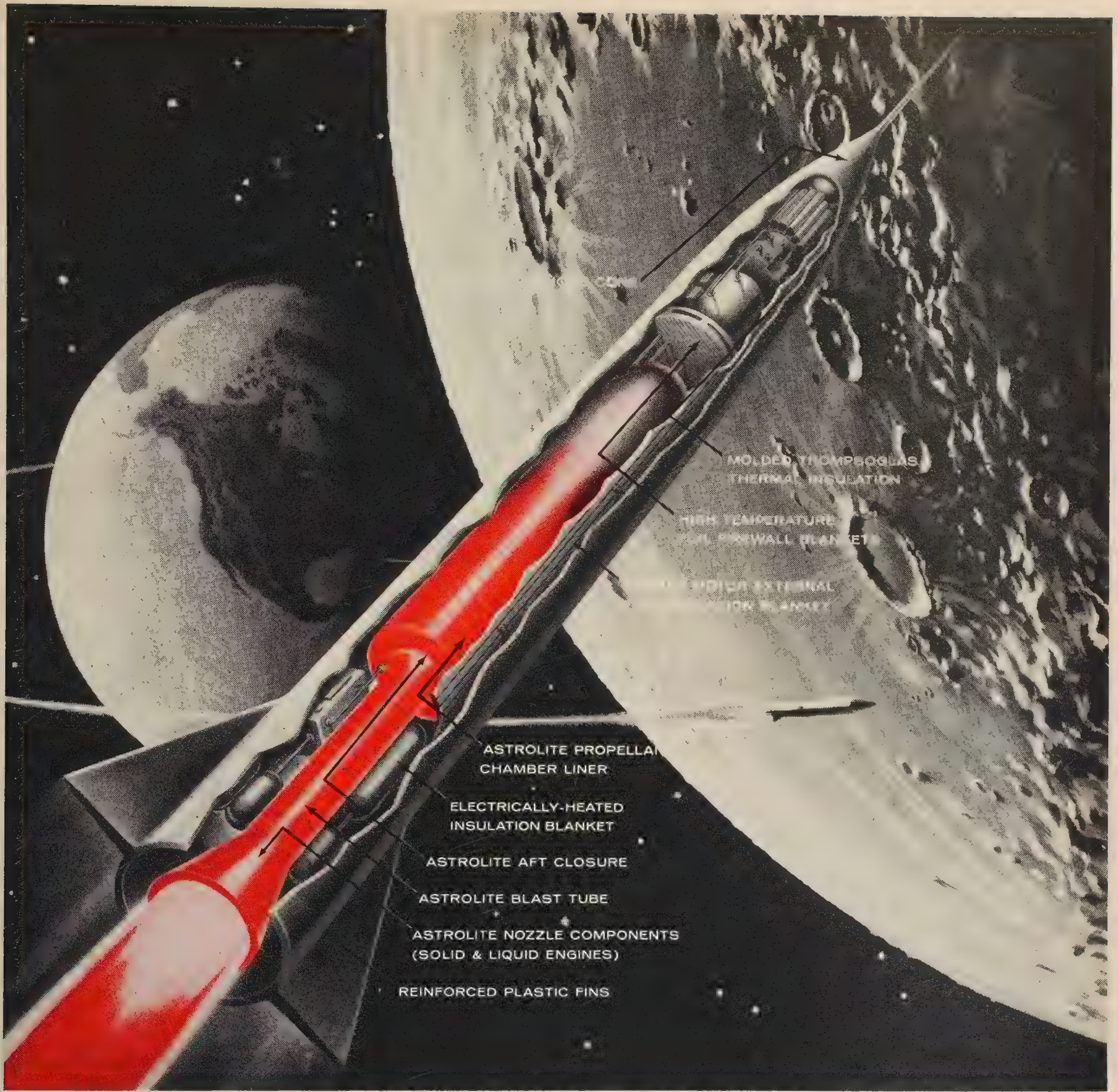


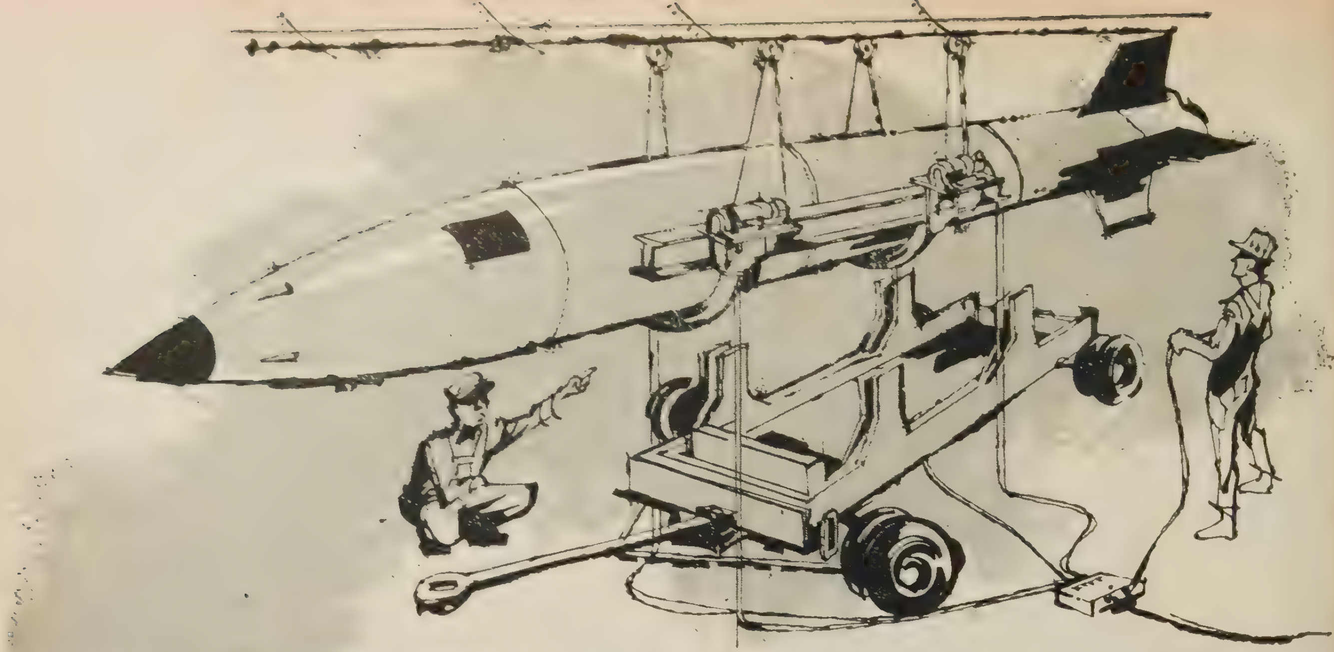
These two auxiliary actuators have been designed for use with the 1SX1-T sub-subminiature switches in applications such as aircraft relays, computers, rocketry equipment, and satellite gear, says **Micro Switch Div., Minneapolis-Honeywell Regulator Co., Dept. S/A, Freeport, Ill.** The corrosion-resistant steel actuators absorb the side thrust that a cam or slide might exert on the switch plunger.

Catalog Listing JX-40 has a leaf actuator to accommodate low angle or slow moving cams or slides, and Listing JX-50 has a roller leaf actuator for rapid cam or slide operation.

Write in No. 434 on Reader Service Card

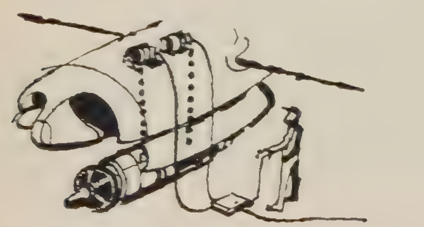
more on page 298


ASTROLITE PROPELLA
CHAMBER LINER
ELECTRICALLY-HEATED
INSULATION BLANKET
ASTROLITE AFT CLOSURE
ASTROLITE BLAST TUBE
ASTROLITE NOZZLE COMPONENTS
(SOLID & LIQUID ENGINES)
REINFORCED PLASTIC FINS

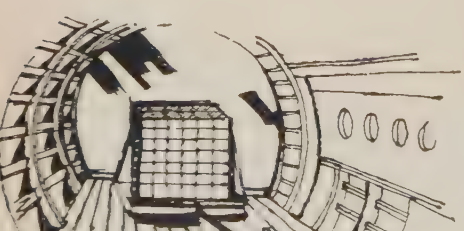


NEW AAE MULTI-HOIST SYSTEM

Airborne applications of the AAE hoist system include external cargo handling of materials by helicopters.



Aircraft and missile ground handling operations require the lightweight and precise control of the AAE hoist system.

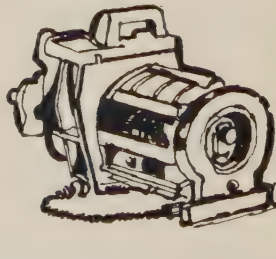


Single-hoist AAE systems are used aboard air-cargo carriers for swift, accurate handling of heavy loads.

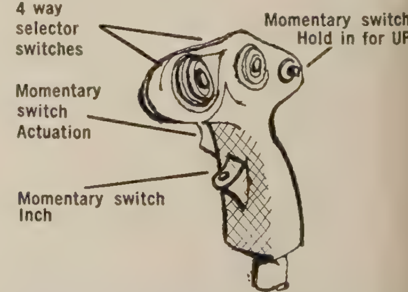
All American Engineering, specialists in lightweight, special-duty precision winches, now offers a multi-hoist control package utilizing the service-proven Model 61 winch and a newly-developed, one-hand, control system. Current applications include the adoption of the AAE multi-hoist system for the North American Aviation B-70 advanced global bomber.

Available in single, double or four-winch packages, the AAE hoist system can be used for ground or airborne applications. The lightweight, compact Model 61 winches can be mounted on the floor or overhead, upside down or right side up. The simple hand control of the hoist system permits the operator to start, stop and reverse all winches, or to adjust the load by inching along with only one or two winches.

The new AAE multi-hoist system is particularly applicable to the precision requirements of the aero/space age. In addition to its military and civilian uses for aircraft and missile operations, either ground or airborne handling, the AAE multi-hoist system has specialized applications for materials handling, construction and maintenance work.



A 50-pound winch with a 3-ton lift capacity, the Model 61 is compact and complete with a self-contained motor.



The pistol-grip control is simple, accurate, easy to operate. Load movement can be controlled down to one-eighth of an inch.

To find out how the AAE Multi-Hoist System fits your handling requirements, write to:

AAE

RESEARCH • DESIGN • MANUFACTURE

ALL AMERICAN ENGINEERING COMPANY

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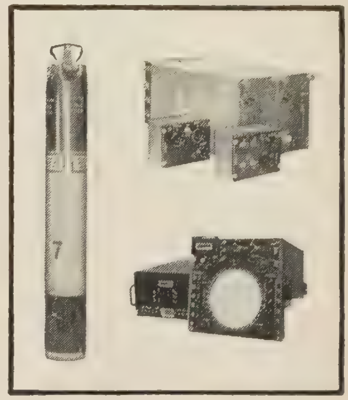
Write in No. 197 on Reader Service Card at start of Product Preview Section

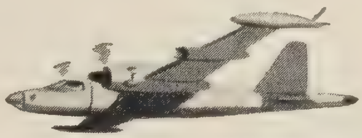
AN ASW SYSTEM...DISPLAY/AIRBORNE RECEIVER/SONOBUOYS

Anti-submarine warfare equipment designed, developed and produced by *The Magnavox Company*, in conjunction with the Navy Department, provides patrol aircraft with eyes that see underwater by day and by night. The AN/ASA-16 Display System, together with SONOBUOYS, AN/ARR-26 Receiver systems and other associated equipment provide aircraft with a clear picture of the ocean-depths below them. They are part of the continuing contributions of *The Magnavox Company* in aiding the U.S. Navy to combat the growing submarine menace.

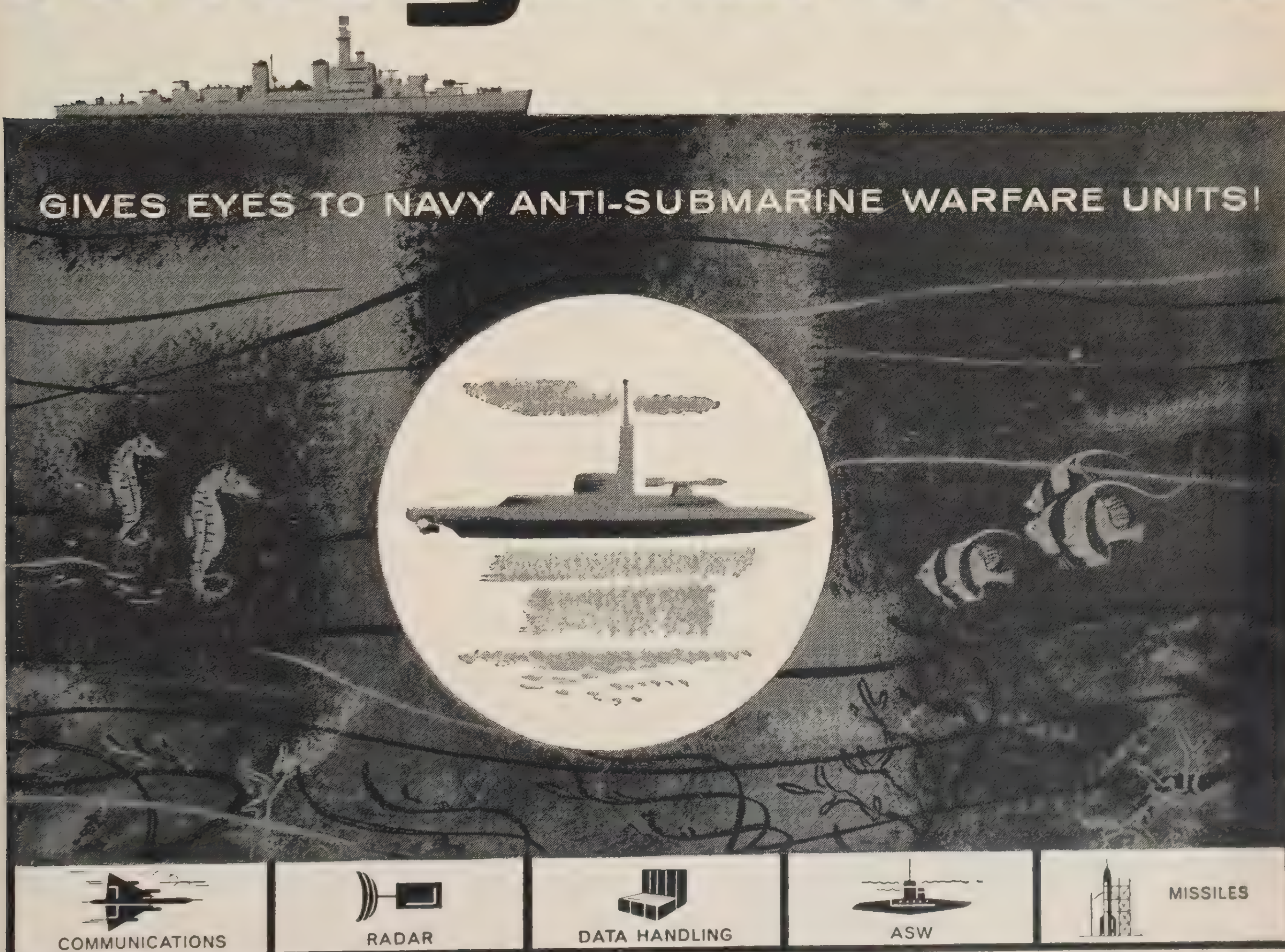
MAGNAVOX capabilities are in The Fields Of Airborne Radar, ASW, Communications, Navigation Equipments, Fusing and Data Handling . . . your inquiries are invited.



PRODUCTS THAT SEE BY THEMSELVES



Magnavox



THE MAGNAVOX CO. • DEPT. 122 • *Government and Industrial Division* • FORT WAYNE, IND.

Write in No. 198 on Reader Service Card at start of Product Preview Section

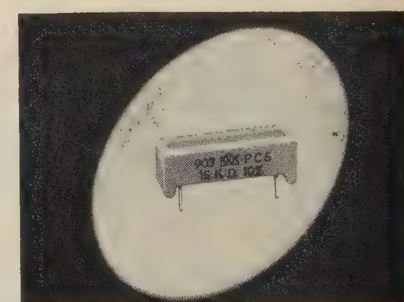
RHENIUM METAL for high temperatures

Wrought rhenium for rod, wire, and strip with a melting point of 5756 F. is surpassed by only one metal, tungsten, and one nonmetal, carbon, according to **Chase Brass & Copper Co., Dept. S/A, 236 Grand St., Waterbury 20, Conn.** While not a structural metal, rhenium holds promise as a welding material for molybdenum, either pure or alloyed with molybdenum.

The electrical properties of rhenium may allow a major breakthrough, it was said, in the critical search for more reliable electrical and electronic components.

Write in No. 435 on Reader Service Card

FIVE-WATT RESISTOR for printed circuit use



Type PC 5, a low-operating-temperature 5 watt resistor, is designed for printed circuit use. All materials are inorganic for fullest protection against flame or decomposition at overload conditions says **International Resistance Co., Dept. S/A, 401 No. Broad St., Philadelphia 8, Pa.**

Alloy-coated leads for positive soldering are secured to a resistance element uniformly and tightly wound on a glass fibre case, and sealed in a rectangular ceramic case.

Write in No. 436 on Reader Service Card

INSULATORS hermetically sealed

These teflon feed-thru insulators are designed for permanent and demountable applications. The permanent type, CF-400, incorporates a hermetic solder seal. The semi-permanent seal, CF-414, utilizes silicone rubber O rings, according to **Fluorocarbon Products, Inc., Dept. S/A, Camden 1, N. J.** The CF-400 provides a fluorocarbon metal fused seal permitting soldering directly to the deck. It is said to be capable of holding a vacuum and containing oil for indefinite periods.

The CF-414 is moisture proof. Both use nickel plated brass hardware for corrosion and weather resistance.

Write in No. 437 on Reader Service Card

more on page 300

now...Streamliner service on fabricated parts

FIF

Fabricator of Industrial Formica laminated plastics

Formica® Field Fabricating better 3 ways:

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3 24-hr. delivery on standard Formica sheets and rods

Need a part fabricated quickly for prototype development? Need a truckload of parts to keep your production lines running? Call your local Fabricator of Industrial Formica laminated plastics. One or one million, he'll *fabricate and deliver* your Formica laminated plastic parts on a Streamliner schedule—within 24 hours in some cases.

He's located near you, offers more frequent contact. In many cases he stocks standard Formica sheets and rods for Streamliner delivery in a matter of hours.

The new Formica field fabricating service is without equal. It can save you time and money in more efficient parts procurement. Write us for complete information and the name of the fabricator nearest you. Formica Corporation, subsidiary of American Cyanamid, 4538 Spring Grove Ave., Cincinnati 32, Ohio.

FORMICA *a product of* CYANAMID

FI-2076

Write in No. 200 on Reader Service Card at start of Product Preview Section

VIBRATION TESTING SYSTEM rated at 175 KVA power output

This wide-band A-182 Shaker is rated at 25000 lb force output over a range from 5 to 2000 cps, says **Ling Electronics, Inc., Dept. S/A, Culver City, Calif.** The 4-cubicle assembly measures 18 ft in overall length and 5 ft in depth and almost 6 ft in height.

Included features are the 340 lb extended webbed-aluminum armature for maximum armature rigidity and the exclusive symmetrical-loop flexure suspension which provides resonant-free rectilinear motion with high transverse stiffness.

Write in No. 438 on Reader Service Card

POWER FERRITE for low frequencies

Type R-03 power ferrite has an almost perfectly rectangular hystereses loop that provides high-efficiency operation in the frequency range from 400 cps to 1500 cps, says **Allen-Bradley Co., Dept. S/A, 136 W. Greenfield Ave., Milwaukee, Wisc.**

The magnetic properties of the ferrite are: saturation induction at 10 oersted, 3900 gauss; remanence induction 3360 gauss; coercive force 0.37 oersted; and maximum differential permeability of 40,000, with d-c test current in all cases.

Write in No. 439 on Reader Service Card

LIGHTHOUSE TRIODE for high frequency application

The metal ceramic GL-6771 tube is particularly suited for use as a continuous wave oscillator to frequencies as high as 4000 mc/sec. Used as such, it offers 200 to 300 mw of nonsquegging CW power, says **General Electric Co., Dept. S/A, Schenectady 5, New York.**

As a frequency doubler 1000 mc, 2 w of output power may be obtained with only 300 mw of driving power. The approved construction has resulted in extremely small size—2⅝ in long and 19/32 in. in diam exclusive of the grid flange—lightweight, increased resistance to vibration and thermal stability of the electron structure.

Write in No. 440 on Reader Service Card

DIGITAL VOLTMETER is completely transistorized

Model V-34 stepping-switch Digital Voltmeter automatically measures voltages from ±100 microvolts to ±1000 volts. The logic circuits are completely transistorized resulting in the fewest stepping switch operations possible during the balancing process, says **Non-Linear Systems, Inc., Dept. S/A, Del Mar, Calif.**

For maximum life and ease of maintenance the unit uses stepping switches sealed in oil, in individual, interchangeable, plug-in containers which can be removed instantly. Facility for operating and controlling digital data printers is standard in very model; no printing control module is necessary.

Write in No. 441 on Reader Service Card

IONIZATION GAUGE will measure ultra-high vacuums

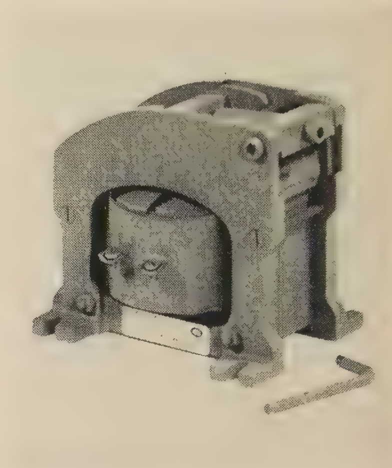
Model 2205-01 is a modified ionization gauge which insures more accurate measurement of vacuums down to 10^{-10} mm hg, and permits direct reading down to 10^{-12} mm hg, says **NRC Equipment Corp., Dept S/A, 160 Chalremont St., Newton, Mass.** Highest full-scale reading is 10^{-3} mm hg; and lowest 10^{-10} mm hg.

Write in No. 442 on Reader Service Card

more on page 302

5 to 50 ton capacities. Write Coles Cranes, Inc., Joliet, Illinois

VARIABLE INDUCTANCE CORES are silicon-iron type



Vari-Henry, adjustable inductance, is available in two types: A single winding type having a ratio of maximum to minimum inductance in excess of 6 to 1, a two winding type for series of parallel connection, having a ratio of maximum to minimum inductance in excess of 24 to 1, says **Magnetic Specialties, Inc., P.O. Box 476, Trenton, N.J.**

Vari-Henry core sizes and windings are engineered to meet individual needs. In 60 cps applications, VA ratings range from 150 VA for the smallest units to 800 VA for the largest units.

Write in No. 443 on Reader Service Card

PUSH-BUTTON SWITCH environment free

This sealed push-button switch has overall dimensions ¾ in. in diameter and 1½ in. high. A combination of an O-ring in the stem containing the plunger and potting around the leads seals out dirt, moisturen and oil, according to **Electrosnap Corp., Dept. S/A, 4220 W. Lake St., Chicago 24, Ill.** The stem and pushbutton plunger are stainless steel, the housing monel.

A scraper built into the stem prevents ice and dirt from fowling the plunger.

Write in No. 444 on Reader Service Card

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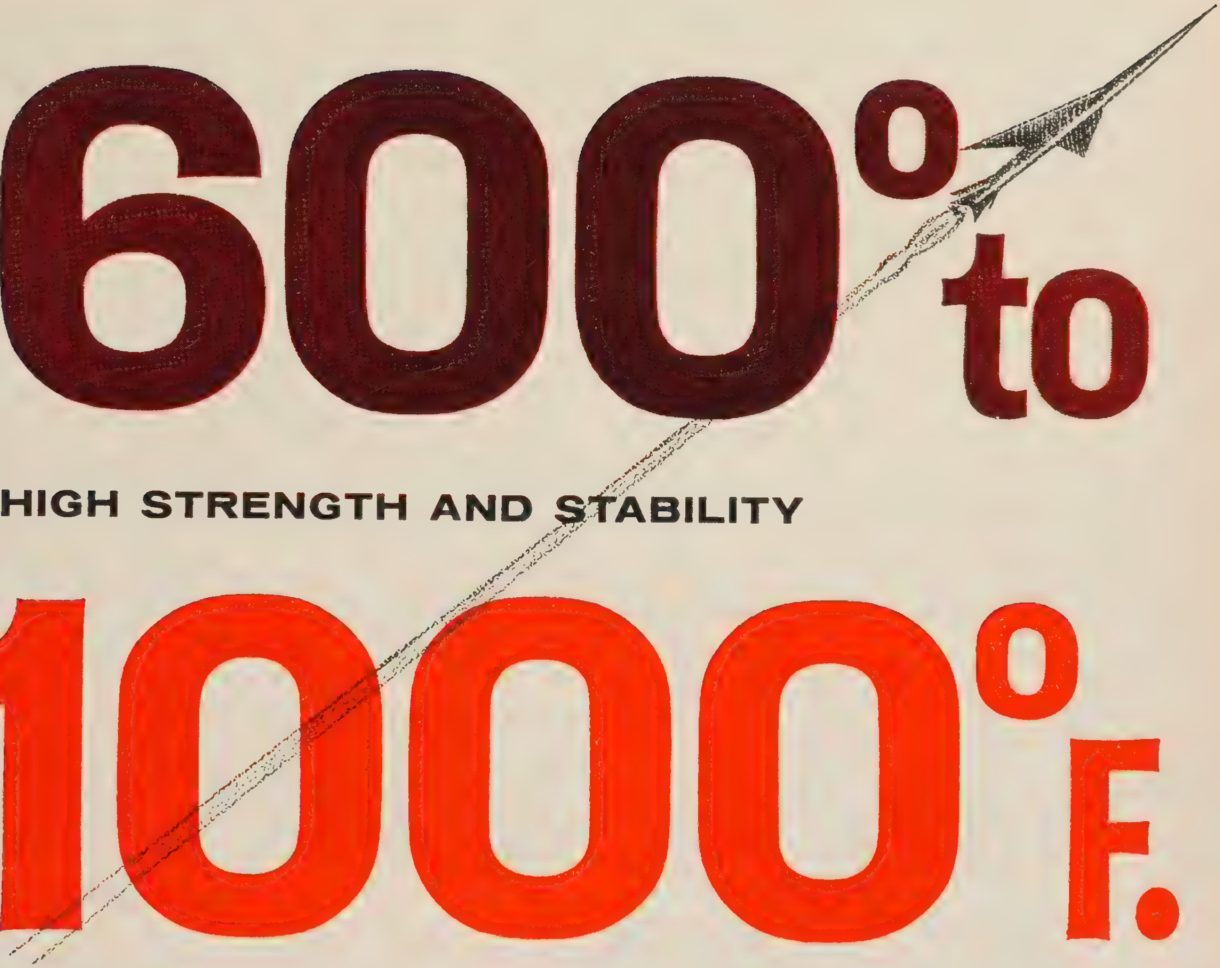


600° to

HIGH STRENGTH AND STABILITY

1000° F.

WITH GOOD FABRICATION PROPERTIES

AM 350 and AM 355 are metals for the space age! The combination of easy fabrication with high strength-to-weight ratio of AM 350 and AM 355 interests missile and supersonic aircraft designers with problems of high strength at elevated temperatures.

This pair of precipitation hardening stainless steels from Allegheny Ludlum research are easy to fabricate in the annealed condition. They can be spun, drawn, formed, machined, brazed and welded using normal stainless procedures.

Both alloys have high strength without embrittlement from room temperature to 1000°F, plus good ductility at elevated temperatures. They have remarkable stability and excellent corrosion resistance.

AM 350 is available in sheet, strip, foil, small bars and wire. AM 355, best suited for heavier sections, is available in forgings, forging billets, plates, bars, wire, sheet and strip.

For further information, see your A-L sales engineer or write for the new technical booklet, "AM 350 and AM 355," **Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.**

822

ALLEGHENY LUDLUM

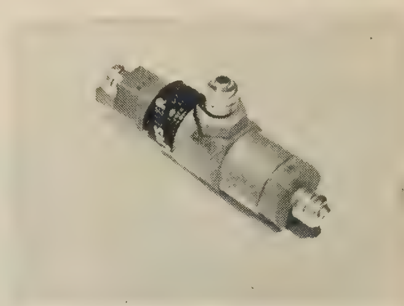
AL

EVERY FORM OF STAINLESS . . . EVERY HELP IN USING IT

Write in No. 204 on Reader Service Card at start of Product Preview Section

PRODUCT PREVIEW

VALVE protects pressure gauges



Ultra-sensitive, low pressure wind tunnel and environmental chamber instrumentation can be protected down to minus ten psig by this low-cost, small valve, says **Fisher Controls, Inc., Dept. S/A, 1928 Lincoln Blvd., Santa Monica, Calif.** The unit utilizes a reference pressure port.

Maximum weight of the device, which is available in 11 combinations of pressure connections, is five oz.

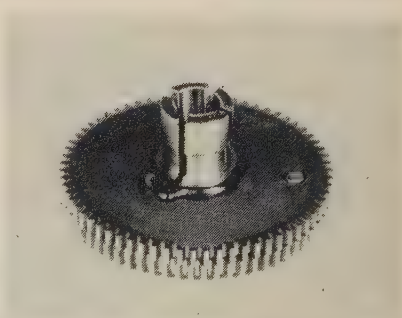
Write in No. 445 on Reader Service Card

MICROWAVE ABSORBER in rod form

Rodite No. 75 microwave absorbing material is now available in rod form —in convenient sizes for experimental fabrication, says **Radar Design Corp., Dept. S/A, Packard Drive, Syracuse 11, N.Y.** The material is recommended in the design of microwave attenuators and terminations.

Write in No. 446 on Reader Service Card

MINIATURE GEARS anti-backlash



These anti-backlash gears for use in servo and instrument designs have an overall length 5/16 in in the clamp-on version. An internal spring is used and the floating gear is prewound and restrained. Gear assembly is meshed merely by displacing the floating portion ½ tooth, says **Precision Mechanisms Corp., Dept. S/A, 577 Newbridge Ave., E. Meadow, N. Y.** They meet Mil-E-5400 requirements.

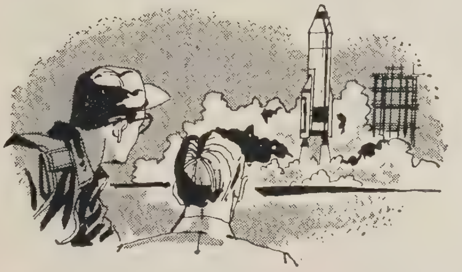
The standard gears are 96 pitch, size range is 66 to 110 teeth, bores are .090, .120, and .125. Tolerances are in accordance with AGMA precision 1 or better.

Write In No. 447 on Reader Service Card

more on page 306

Automatic Wire-Wrap® machine speeds production on vital military project

FOR THE CHALLENGE OF TOMORROW



Ever looking ahead to the challenge of tomorrow, Gardner-Denver men constantly seek new and better ways to cope with the growing complexity of industry and the resultant tough problems that lie ahead. At Gardner-Denver there's no substitute for men—our 100-year philosophy of growth.

To produce electronic equipment containing literally *thousands* of connections packed into a small space—that was the problem facing engineers recently on an important new military project. The solution came in the form of this unique "Wire-Wrap" machine—designed and built by Gardner-Denver.

Operated either manually or automatically by punched cards or tapes, the machine can place 10,000 wires on a 20″ x 20″ modular terminal board. It wraps all terminals for lastingly secure, solderless connections—in a 10″ x 10″ wrap area—and puts as many as three connections on each terminal, completing the entire wrapping cycle for one wire in approximately six seconds.

This is just one more example of special machines designed and built for *reliability*—by Gardner-Denver. If you have a special problem in multiple operations of connecting wires, drilling holes, or fastening screws and nuts, it'll pay you to talk to a Gardner-Denver special machines engineer. Ask for bulletins.

GARDNER-DENVER Since 1859

100 1959 YEARS

EQUIPMENT TODAY FOR THE CHALLENGE OF TOMORROW

GARDNER - DENVER

Gardner-Denver Company, Quincy, Illinois

In Canada: Gardner-Denver Company (Canada), Ltd., 14 Curity Avenue, Toronto 16, Ontario

Write in No. 206 on Reader Service Card at start of Product Preview Section

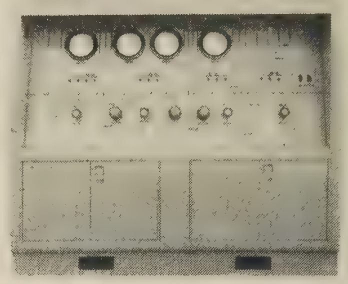
SOLID STATE RELAY has no moving parts

This solid state relay features no moving parts, yet has snap action characteristics with a pick-up time of about 5 usec and drop-out time of about 30 usec, says **Pendar Inc., Electronics Div., Dept. S/A, P.O. Box 3355, Van Nuys, Calif.**

The 28 vd-c coil circuitry is completely isolated from the switching circuit and the unit responds to 18 volts pick-up and 11 volts drop-out. Temperature range is from −55 deg F. to + 160 deg F.

Write in No. 448 on Reader Service Card

GAS CONTROL CONSOLE for high pressure



Designed as ground support equipment for use during checkout and launching of an ICBM, this model 13581 high pressure gas console accepts inert gas from four external inlet pressure sources up to 8000 psig and provides twelve outlets which are precisely regulated from three to 5500 psig, according to **Haskel Engineering & Supply Co., Dept S/A, 1236 So. Central Ave., Glendale 4, Calif.** It comprises four sections, or sub-systems, operated independently or simultaneously.

Pressure sources ranging from 1300 to 8000 psig connect to the four-system inlets.

Write in No. 449 on Reader Service Card

more on page 308

IT'S A TEAM AT T&W

that helps you DEVELOP and GET the part you need

When you go to T & W for forgings or stampings, an entire team swings into action. Experts working together solve problems and get results — perform at a level far above that which "routine" handling provides. *T & W Technique* develops for you forgings and stampings meeting your most exacting needs.

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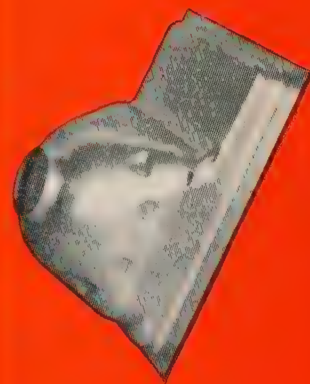
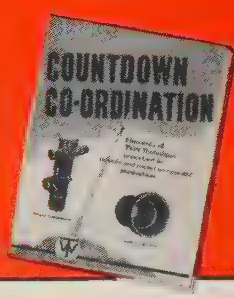
HOUSTON • LOS ANGELES

The forging in the illustration at left is a missile part, meeting requirements of the exacting kind encountered for rocket, missile, and aircraft production.



T & W Technique makes possible production of many parts unusual in contour or tolerance, from various alloys. Above is a stainless steel stamping a tank 25″ x 18½″ x 12½″.

Write for COUNTDOWN COORDINATION, showing how T & W facilities can help you.



FORGINGS & DEEP DRAWN STAMPINGS

TRANSUE & WILLIAMS
ALLIANCE, OHIO, U.S.A.

Name ________ Title ________
Company ________
Street ________
City ________ State ________

Write in No. 150 on Reader Service Card at start of Product Preview Section

TRANSISTOR TRANSFORMERS for power supplies

The TY series of transformers are designed for use in transistor power supplies. The units provide d-c outputs from mobile supplies of either 6, 12, or 28 Vd-c, says **Triad Transformer Corp., Dept S/A, 4055 Redwood Ave., Venice, Calif.**

The operating frequency falls in the range between 2500 cps for higher power units, to 5000 cps for the low-power line. These rugged and compact units can be stacked on a single mounting bolt through a centrally located hole, and series-parallel connections are easily made to the terminal pins.

Write in No. 450 on Reader Service Card

CRYOSTAT COOLING SYSTEMS improve infra-red detector units

Two types of cryostat cooling systems, designed to improve the sensitivity and spectral response of infra-red detector units on missiles, says **The Garrett Corp., Dept. S/A, 9851 Sepulveda Blvd., Los Angeles 45, Calif.**

Specifically the AiResearch Systems cool the semiconductor elements which detect infra-red radiation produced by heat from the target which the missile is seeking. One system uses liquid nitrogen at low pressure with a special Dewar flask. Another method uses nitrogen gas contained at high pressure.

Write in No. 451 on Reader Service Card

EPOXY RESIN SYSTEM is flexible

Hysol 6621 is a flexible epoxy resin system with an exceptional wide range of possible cures and can be used for potting transistorized circuits and transformers having strain sensitive cures, says **Houghton Lab, Inc., Dept. S/A, Houghton Ave., Olean, N.Y.**

Providing excellent resistance to thermal and mechanical shock, castings of Hysol 6621 containing large steel inserts of various configurations have been cycled between −65 and +150 deg C with no cracking.

Write in No. 452 on Reader Service Card

KRT has high resolution

Drive requirements for the WX-3798 cathode ray tube is from five to ten V for peak brightness as compared to 35 to 40 V for conventional tubes, says **Westinghouse Electric Corp., Dept. S/A, Box 2278, Pittsburgh, Pa.** The high-resolution tube, an electrosatic focus, magnetic-deflection type for transistorized video amplifiers, produces a scanning line 0.0015 in wide, and video bandwidths up to 20 mc can be achieved.

A specially ground P-11 phosphor and a metal-backed screen are used to obtain maximum light output. The 13½ in tube has an optically flat facepate.

Write in No. 453 on Reader Service Card

CONNECTORS with snap-in contacts

Miniature electrical connectors with snap-in contacts and crimp-type terminations feature insertable and removable pins and sockets, formulated and molded silicone inserts, continuous dielectric separation with no voids, and an exclusive ball-lock coupling ring, says **Deutsch Co., Dept. S/A, 7000 Avalon Blvd., Los Angeles, 3, Calif.** Delivered completely assembled except for insertion of contacts.

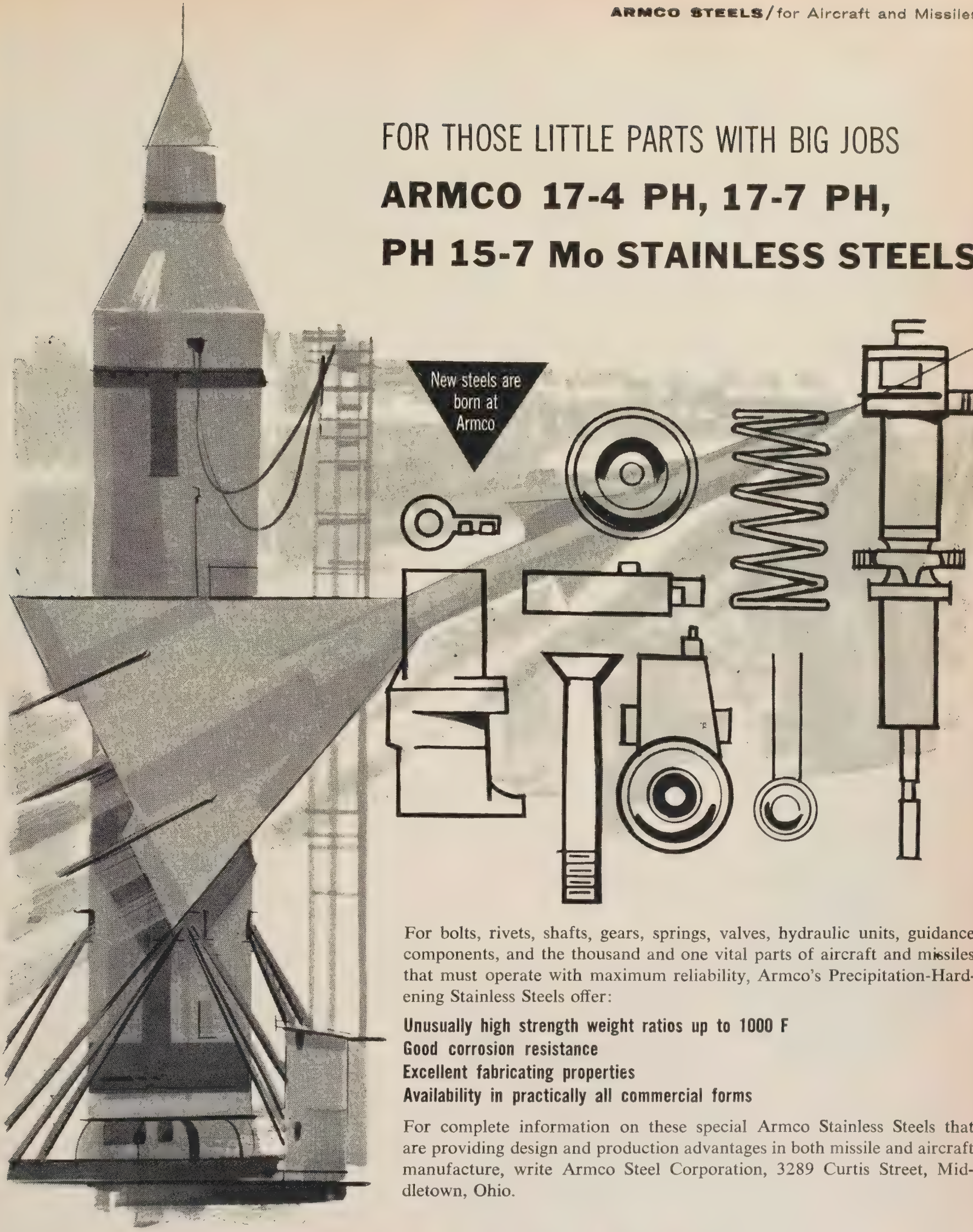
They are unaffected by temperature extremes from −100 deg to an excess of 300 deg F and meet or exceeds applicable requirements of MIL-C-5015.

Write in No. 454 on Reader Service Card

more on page 310

FOR THOSE LITTLE PARTS WITH BIG JOBS

ARMCO 17-4 PH, 17-7 PH, PH 15-7 Mo STAINLESS STEELS



For bolts, rivets, shafts, gears, springs, valves, hydraulic units, guidance components, and the thousand and one vital parts of aircraft and missiles that must operate with maximum reliability, Armco's Precipitation-Hardening Stainless Steels offer:

Unusually high strength weight ratios up to 1000 F
Good corrosion resistance
Excellent fabricating properties
Availability in practically all commercial forms

For complete information on these special Armco Stainless Steels that are providing design and production advantages in both missile and aircraft manufacture, write Armco Steel Corporation, 3289 Curtis Street, Middletown, Ohio.

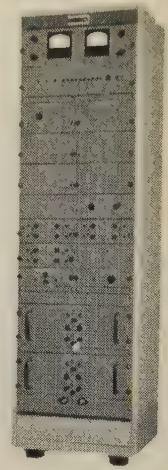
ARMCO STEEL

ARMCO

Armco Division • Sheffield Division • The National Supply Company • Armco Drainage & Metal Products, Inc. • The Armco International Corporation • Union Wire Rope Corporation

Write in No. 211 on Reader Service Card at start of Product Preview Section

LINKAGE SYSTEMS for analog-digital computers

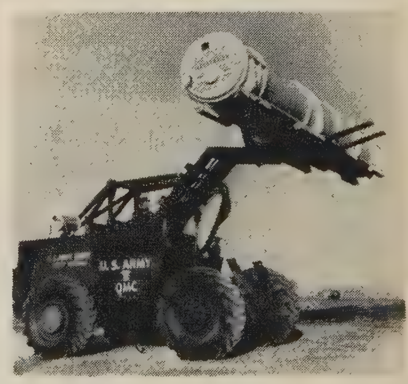


This system employs a number of information channels to convert analog outputs into digital form and digital computer outputs into analog form. More than 400 conversions per sec may be made on any channel with a conversion accuracy of 0.05 per cent says **Electronic Assoc. Inc., Dept. S/A, Long Branch, N.J.**

Solid state circuitry on etched circuit cards is used to assure reliability, low power consumption and compact construction. System can be grounded with virtually any number of A-D or D-A channels as determined by individual requirements.

Write in No. 455 on Reader Service Card

MISSILE HANDLER does triple job



This multi-purpose vehicle for handling missiles at launching sites acts as a self-loading truck, a towing tractor and a crane. Called the "Telefork 102," it was designed to carry five tons of missile components over sand dunes, through snowbanks and through five feet of water, says **Clark Equipment Co., Dept. S/A, 24th St., Battle Creek, Mich.**

A towing hook mounted on the rear of the vehicle allows it to pull missile trailers around launching sites.

Write in No. 456 on Reader Service Card

more on page 312

MANAGEMENT

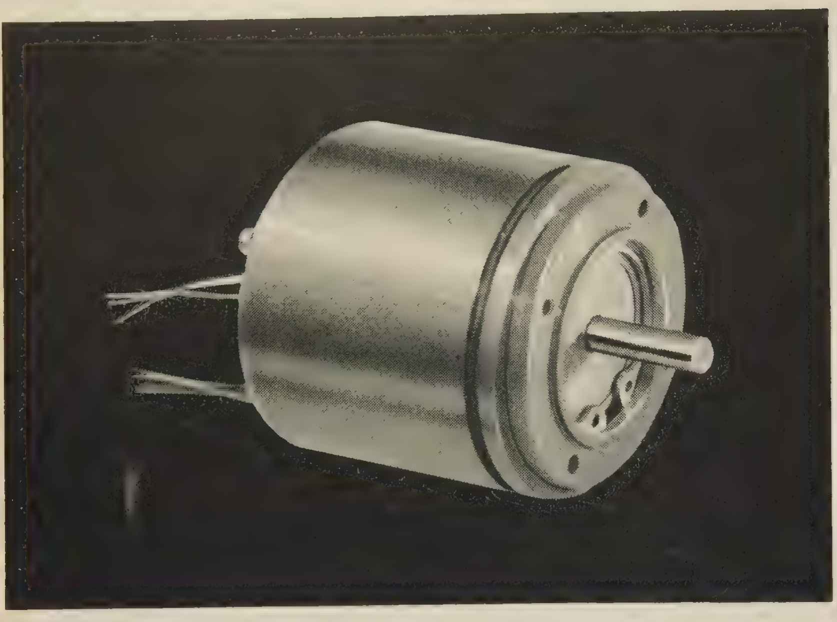
Management moves men toward common goals. But at Cape Canaveral, where we assist the Air Force in management of the Atlantic Missile Range, common goals are uncommon – even extraordinary. Here is a management involving unparalleled projects – *Juno, Jupiter, Vanguard, Thor, Atlas, Titan, Polaris;* extending over an incredible area – two continents, twelve islands and one ocean; working toward unprecedented achievements – the development of reliable ballistic missiles and the exploration of space. For Pan American, this experience has meant the expansion of our unique capability for large-area systems management. For members of our technical staff, it has meant the opportunity to achieve new personal goals, and to develop unusual professional skills, through scientific teamwork, coordination, and management. Other engineers and scientists, particularly those experienced in the areas of quality control, facilities engineering and electronics, should investigate the uncommon opportunities of a career with Pan Am. Please address your inquiry to Mr. J. B. Appledorn, Director of Technical Employment, Pan American World Airways, Inc., Patrick Air Force Base, Florida, Dept. T-10.

GUIDED MISSILES RANGE DIVISION • PATRICK AIR FORCE BASE, FLORIDA

PAN AM

Check Employment Inquiry Form on Page 217

ENGINEERING REPORT ON BENDIX COMPONENTS



ONE-MINUTE SYNCHRO SYSTEM ACCURACY

Electrical two-speed Autosyn* synchro features—

- ACCURACY UNAFFECTED BY THERMAL AND MECHANICAL STRESS
- HIGH SIGNAL-TO-NULL RATIO
- ELIMINATION OF GEAR ERROR FOUND IN MECHANICAL TWO-SPEED SYSTEM
- ADAPTABILITY TO GYRO PICKOFF

Developed to meet need for accurate data transmission with maximum system simplicity. Produces two electrical outputs from single shaft, thereby eliminating inaccuracies of two-speed gear system as well as installation and maintenance costs of additional unit.

The synchro contains two separate sets of windings. One set produces the normal signal pattern of one cycle of output voltage, while the other produces eleven cycles, for each rotation of the synchro shaft. Increase in accuracy is very close to the 11-to-1 theoretical maximum, resulting in a system error of ±1 minute when used back-to-back with similar units.

*REG. U. S. PAT. OFF.

ADDITIONAL CHARACTERISTICS:

Input voltage (to rotor)	26 volts, 400 cycles, single phase
Input current	200 ma max.
Input power	2.5 watts max.
Signal-to-null ratio	350:1
Sensitivity (mv/degree)	3500

For more detailed information on specific applications, write—

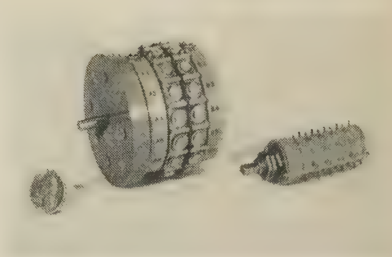
Eclipse-Pioneer Division
Teterboro, N. J.

Bendix AVIATION CORPORATION

District Offices: Burbank and San Francisco, Calif.; Seattle, Wash.; Dayton, Ohio; and Washington, D. C.
Export Sales & Service: Bendix International, 205 E. 42nd St., New York 17, N. Y.

Write in No. 215 on Reader Service Card at start of Product Preview Section

ROTARY SWITCH for high altitudes

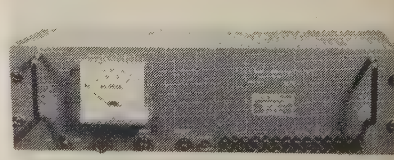


This rotary selector switch is said to be the smallest known qualified totally enclosed multi-wafer constructed unit of its kind currently produced. Reliable performance at altitudes up to 80,000 ft result from the choice of Plaskon Alkyd 446 to critical components of the part, says **Janco Corp., Dept. S/A, 3111 Winona Ave., Burbank, Calif.**

Benefits claimed for the switch include reduction in size and weight, high current capacity and dielectric strength and increased electrical capabilities. Designed to meet and exceed MIL-S-6807A, the part is characterized by high impact strength. It measures one inch in diameter and has up to ten live positions (36 index). Other specifications include: Make and Break: five amperes-115 Vac, three amperes-28 Vdc, with a life of 10,000 double cycles at rated amperage with a potential drop of less than 100 mv.

Write in No. 273 on Reader Service Card

PAM/PDM DECOMMUTATOR has solid state design



A PAM/PDM decommutator system that will accept all standard IRIG data trains is said to be the first truly solid state telemetry device of its type developed. System accuracy is better than plus or minus one per cent, and stability rating shows a shift of under one per cent in dc output over an eight-hr period, says **Missile Electronics Engineering Co., Dept. S/A, 14644 Keswick St., Van Nuys, Calif.**

Output is five V full scale across an internal 4700 ohms. The 1000 Series decommutator weighs under 35 lbs for a 28-channel system and consumes less than ten W. Packaging is available for fully portable operation, standard rack mount, or cabinet use.

Write in No. 274 on Reader Service Card

PROBE
for surface temperature

This new surface temperature probe REC Model 116D, measures skin and gas temperatures, jet engine control, and is especially useful for tailpipe temperature measurements and in flight testing of manned aircraft, rockets and missiles, says **Rosemount Engineering Co., Dept. S/A, 4900 W. 78th St., Minneapolis 24, Min.**

The probe features a sensor of pure platinum wire having 500 ohms resistance at zero deg C, and a1/16 in. inconelsheathed lead (between a flexible cable and the probe) that can be bent to almost any desired shape for hard-to-reach locations. The probe's upper limit of 760 deg C in the standard model can be raised to 1100 deg C, it is claimed.

Write in No. 275 on Reader Service Card

DIGITAL RECORDER
for motion picture use

Developed by Magnovox Research Lab, the Digital Recorder used with the Traid 35 mm motion picture cameras provides 96-bit matrix image on each frame of film and correlates coded data with pictorial records in real times, says **Traid Corp., Dept. S/A, Ventura Blvd., Encino, Calif.**

The cameras can be operated at any frame rate desired up to 80 frames per sec. At 80 frames per sec, the Traid 75 camera can record 7680 bits of coded information per sec. Traid offers the digital recorder on its 35mm Traid 75 Fototracker and on Bell & Howell Model 71 Eyemo cameras.

Write in No. 276 on Reader Service Card

SELENIUM RECTIFIERS
are miniature

The ABC series selenium rectifiers are completely potted and are available in a wide range of voltages and currents for use in half-wave, full-wave, single or three-phase rectifier circuits, says **General Instrument Corp., Radio Receptor Div., Dept. S/A, 240 Wythe Ave., Brooklyn, N.Y.**

Many different terminal arrangements are available to suit application needs making these units particularly suitable for printed wiring boards.

Write in No. 277 on Reader Service Card

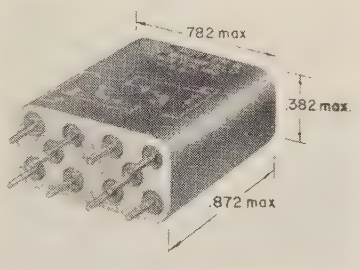
HYDRAULIC VALVE
for high temperatures

Hydraulically activated, remote-control valves that feature a unique, backless design are now available in a type that may be used in continuous service at temperatures to 250 deg F, says **Automatic Valve Systems Co., Dept. S/A, 1535 Monrovia Ave., Newport Beach, Calif.** The AVSCO valves have had their range extended through use of a heat-resistant diaphragm material.

The device is closed by hydraulic pressure applied to the valve cover through a small control tube. This pressure is derived directly from the process stream itself, and when it is released, the line pressure lifts open the valve diaphragm and disk. The units, which require no lubrication or packing, are made in sizes from ½ to 16 in., with screwed or flanged connections.

Write in No. 278 on Reader Service Card

MINIATURE RELAY
has automatic assembly



These relays with terminals located on .2 in x .2 in co-ordinates to permit mounting on printed circuit boards by automatic assembly techniques are available on both dual coil magnetic latching and on single coil action relays, says **Potter & Brumfield, Inc., Dept. S/A, Princeton, Ind.** Both relays operate under 100 G shocks and 30 g vibrations to 2000 cps with no contact openings in either armature position.

Relays with single coil action pull-in at 260 milliwatts at 25° C; dual coil latching relays at 230 milliwatts. All coil connections are polarized to take advantage of permanent magnet forces in the relay.

Write in No. 279 on Reader Service Card

more on next page

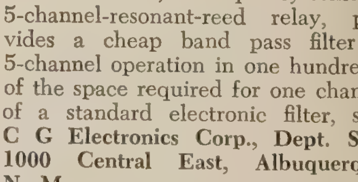
FREE GYRO uses stainless steel

For free gyro applications requiring high performance under extra severe shock and vibration, this FGO1-1300 series free gyro employs high strength stainless steel in the one-piece spindle and gimbal assembly, says **Humphrey, Inc., Dept. S/A, 2805 Cannon St., San Diego, Calif.** It meets prescribed resistance to severe vibration and 60 G shock.

The all-steel design eliminates differences in coefficients of expansion, improving balance and hearing fits. It is 2¾ x 5¼ inches.

Write in No. 280 on Reader Service Card

RESONANT REED RELAYS fill remote control needs



Model AR-5, a frequency-sensitive 5-channel-resonant-reed relay, provides a cheap band pass filter of 5-channel operation in one hundredth of the space required for one channel of a standard electronic filter, says **C G Electronics Corp., Dept. S/A, 1000 Central East, Albuquerque, N. M.**

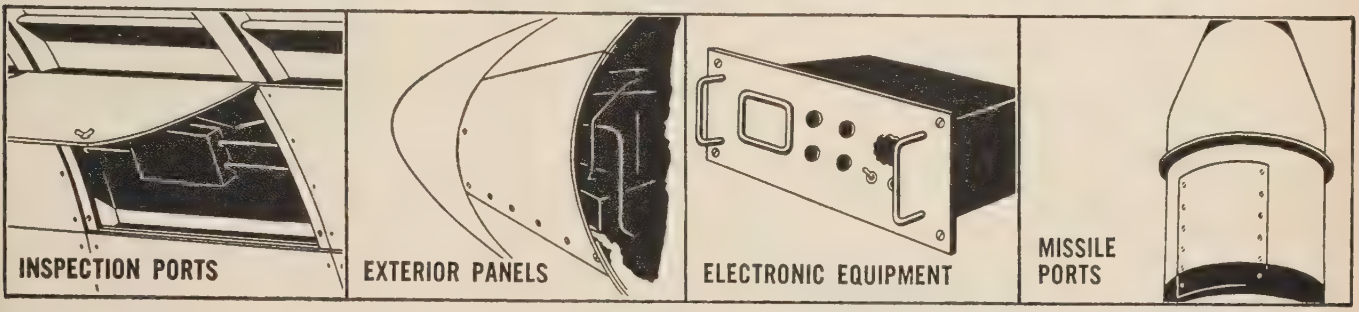
The reed frequencies range from 200 to 500 cps. Minimum driving power for the open frame or the hermetically sealed relays is 1.5 mw with a stability of 0.25 per cent from 0 deg to 25 deg C and 1 per cent from —20 deg C to +80 deg C. The units weigh about ½ oz and measure ¾ in high by ⅝ in wide and 1⅜ in long.

Write in No. 281 on Reader Service Card

more on page 316

FLIGHT-PROVED RELIABILITY...

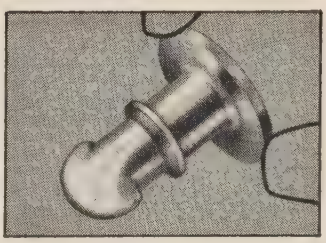
LION *Quarter-turn* FASTENERS FOR SECURING REMOVABLE SECTIONS



Southco's Lion Quarter-turn Fasteners provide quick access and reliable securing of hinged or completely removable panels. Resistance to severe heat, shock and vibration, and a high strength-weight ratio make these unique fasteners ideal for use in private, commercial or military aircraft and missiles . . . for ground production and control or airborne applications.

Lion Fasteners consist of three parts . . . a one-piece, swaged-nose stud; a retainer; a floating receptacle which is riveted or welded in place. Installation requires no special tools . . . is simplified by a permissible float of .070″.

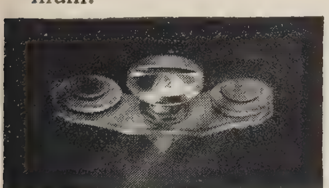
SWAGED NOSE



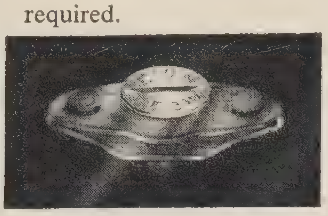
Case hardened one-piece stud with swaged nose has no milled sections, inserts, or cross pins . . . requires no wire spring to hold it in locked position. Lion Fasteners offer the highest weight-strength ratio available.

2 TYPES AVAILABLE

LION NO. 2 FASTENER
For use where space is limited and where weight must be kept at a minimum.

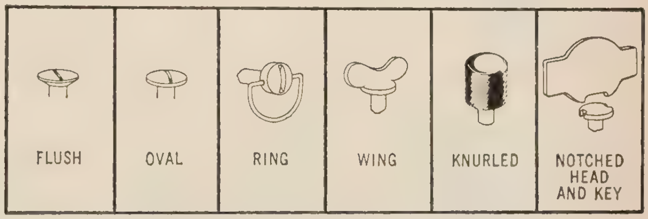


LION NO. 5 FASTENER
For heavy-duty applications where good tensile and shear strength are required.



FULL RANGE OF HEADS

Lion No. 2 Fastener available with flush, oval or wing type. No. 5 with flush, oval, ring, wing, knurled or notched head and key.



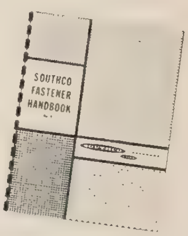
OTHER SPECIFICATIONS

LION NO. 5 QUARTER-TURN FASTENERS CONFORM TO MIL. SPEC. MIL-F-5591A (ASG) . . . ARE ON THE GOVERNMENT'S QPL . . . ARE CAA APPROVED FOR COMMERCIAL AND PRIVATE AIRCRAFT USE.

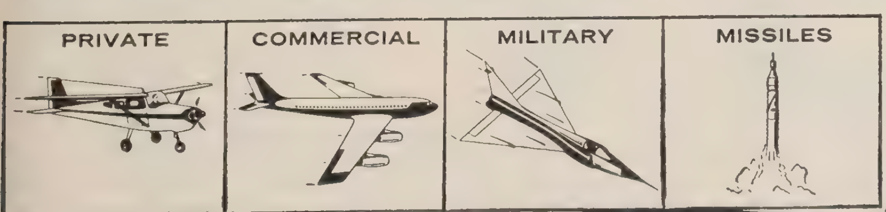
MATERIAL: Cadmium-plated case-hardened steel.

FREE!

FASTENER HANDBOOK



Send for your free copy of Southco Fastener Handbook No. 9. Gives complete engineering data on Lion Fasteners and many other special fasteners. Write to Southco Division, South Chester Corporation, 253 Industrial Highway, Lester, Pa.



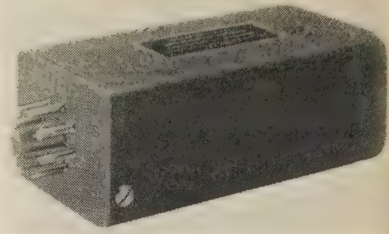
LION *Aviation* FASTENERS

one of the SOUTHCO FASTENERS LION

©1958

Write in No. 271 on Reader Service Card at start of Product Preview Section

CRYSTAL OVEN has long-term stability



Model 35, change-of-state crystal oven, combines small size with precise temperature control, no thermal oscillation or contact noise, low power consumption, and long-term temperature stability, according to **Robertshaw Fulton Controls Co., Dept. S/A, 911 E Broad St., Richmond, Va.**

Thermal Set has a cavity temperature variation less than 0.01 deg C per deg ambient temperature change. The oven measures 7/16 in. x 1⅞ in x 4 1/16 in. with cavity dimensions of 0.92 in diam by 1.635 in deep.

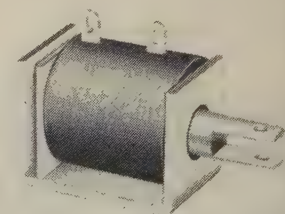
Write in No. 282 on Reader Service Card

VHF PREAMPLIFIERS offer low noise

Model 530 NS broadband VHF preamplifier has a 42 db gain from 50 to 300 mcps. The overall noise figure is less than 8 db, says **Haller, Raymond and Brown, Inc., Dept S/A, Science Park, State College, Pa.** Package weight is 4 lb., less power supply. Power input is 70 W. Other models have bandwiths from 50 to 250 mcps.

Write in No. 283 on Reader Service Card

MIDGET AC SOLENOID for small assemblies



This No. 24 midget solenoid provides maximum power for smaller assemblies and is avilable for intermittent or continuous duty operation, according to **Guardian Electric Mfg. Co., Dept. S/A, 1621 W. Walnut St., Chicago 12, Ill.** Plunger stroke is adjustable from 1/16 up to ⅝ in with maximum life of 12 oz, continuous duty; 19 oz, intermittent.

Coil voltages from 6 to 230v. ac. Small size ⅞x1¼x1 inches.

Write in No. 284 on Reader Service Card

more on page 318

a new, improved ALODINE for aluminum

Cost Saving, Time Saving ALODINE 1200S Pre-Paint Treatment Protects Aluminum Best!

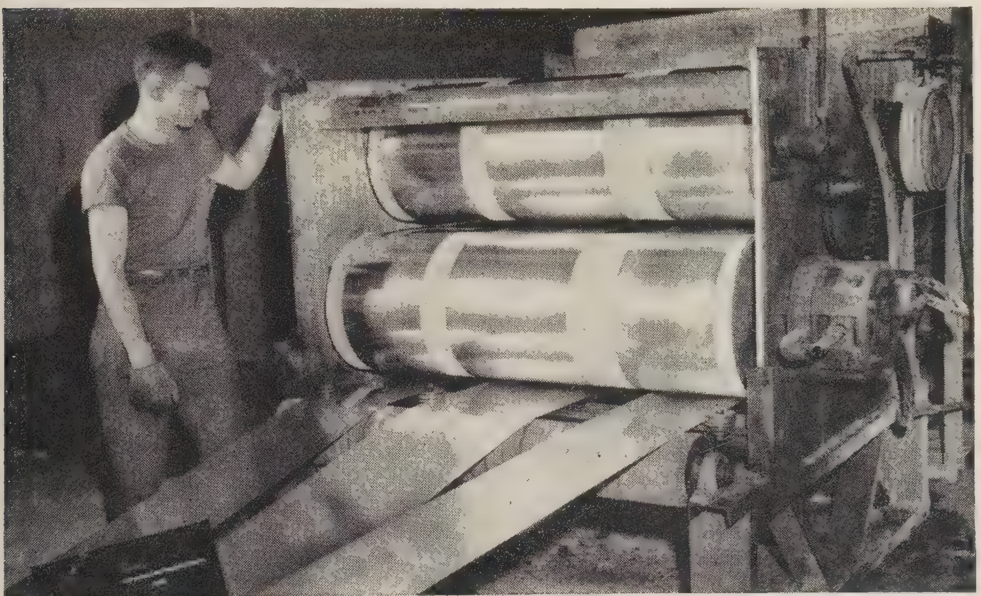
IN LESS TIME—ALODINE 1200S provides increased chemical activity for dramatic reduction in processing time . . . up to 50% in most cases! You get far faster processing than ever before, with the same high quality protection!

WITH LESS EQUIPMENT—You can install an ALODINE 1200S system quickly and conveniently, *without resorting to mechanical bath maintenance!* That means no dangerous, time consuming checking routines with the possibility of bath contamination always present!

AT LESS COST—ALODINE 1200S can be processed through continuous dip in the same time cycle other conversion coatings require for continuous spray lines! This dip technique reduces initial equipment costs, slashes maintenance costs to a minimum and allows aluminum fabricators to utilize conversion coatings more frequently for a wider range of product applications! Whatever the application method—brush, dip, continuous strip or spray—ALODINE 1200S may be the answer to your production problems.

FOR MORE FLEXIBILITY—Most important, its ease of operation, safety in use and versatility enables ALODINE 1200S to answer one of the most perplexing problems inherent in providing corrosion protection and paint bonding qualities for aluminum—the problem of constant, uniform quality. ALODINE 1200S is qualified under Government Specification MIL-C-5541.

Investigate cost saving, time saving ALODINE 1200S today! And whenever you have a chemical finishing requirement for aluminum—any type of aluminum—there's an ALODINE process available to protect or decorate the metal, and anchor the paint finish more securely.



Typical ALODINE 1200S strip line installation at ALSCO, INC. Strip from aluminum coil is fed into Alodine processing baths where it is cleaned, rinsed, deoxidized, rinsed, coated with ALODINE 1200S, rinsed and given a final acidulated rinse. Strip is then rewound, roll coat painted, roller formed into final shape, backed, inspected and packed for final shipment.

Write for Bulletin 1424A describing use of Alodine for aluminum fabrications of all types.

AMCHEM

ALODINE 1200S

another chemical development of **AMCHEM PRODUCTS, INC., Ambler 10, Pa.**
(Formerly American Chemical Paint Co.)

Detroit, Mich. • St. Joseph, Mo. • Niles, Calif. • Windsor, Ont. Amchem and Alodine are registered trademarks of Amchem Products, Inc.

Write in No. 175 on Reader Service Card at start of Product Preview Section

YIG CRYSTALS *have narrow resonance width*

Single crystal yttrium iron garnet, offered on a commercial basis in all sizes up to 0.400 in., weigh up to two gm per crystal, says **Microwave Chemicals Laboratory, Inc., Dept. S/A, 282 Seventh Ave., New York 1, N.Y.** These YIG are suggested for use as parametric amplifiers and superior substitutes for conventional microwave ferrite single crystals.

The crystals have a very narrow resonance line width—under five oersteds at microwave frequencies, and the Curie point is 292 deg C, plus or minus one deg. The crystals have a lattice constant of 12.373 A, ±.003 in. The Yig have been successfully used as a Faraday-rotation type IR modulator.

Write in No. 287 on Reader Service Card

METALLIC SEAL *for hydraulic systems*

These static metallic seals combine infinite shelf life and reusability with effective sealing throughout a temperature range from —350 to 1800 deg F. and under pressures up to 20,000 psi. Sealing efficiency is unaffected by normally encountered structural distortion and mating parts require no unusual machining operations, says **Cadillac Gage Co., Dept. S/A, Costa Mesa, Calif.** Standard sizes machined from age hardened Inconel X are ½ in to 6 in in diameter; up to 60 in on special order.

Seal configuration incorporating an integral back-up ring with twin lip vee sealing surfaces eliminates the overstressing and minimizes design complexity of mating parts, it is said.

Write in No. 288 on Reader Service Card

MULTI-WIRE FABRIC *is a space saver*

This flat belt of interwoven copper wires can pass through a clearing of less than 1/32 in high. The teflon-coated wires are in alignment and are woven by cross threads of nylon, fiber glass or teflon yarn, says **Fletcher Works, Dept. S/A, Philadelphia 40, Pa.** Wires are of different colors.

The multi-wire fabric can be made any width, the number of wires per inch being determined by th diameter of the wire.

Write in No. 289 on Reader Service Card

PRESSURE SWITCH *for missile use*

This miniature pressure switch is for missile and space applications where reliability, light weight are prime, says **Frebank Co., Dept. S/A, 711 W. Broadway, Glendale 4, Calif.** Designated model 3486, it can be used with both hydraulic fluids and gases and for 400 psi to 3000 psi systems.

Bearing a maximum weight of ¾ oz, the switch has a temperature range from — 65 deg F to +275 deg F, a proof pressure of 4500 psi and a burst pressure of 7500 psi.

Write in No. 290 on Reader Service Card

NYLON TUBING *is heat resistant*

This flexible polyamide tubing grade TR, which can be used continuously in an oxidizing atmosphere at temperatures up to 225 deg F, has an expected life of 2 to 5 years in water at temperatures as high as 150 deg F., says **Polymer Corp., Dept. S/A, 2140 Fairmont Ave., Reading, Pa.** It is black in color.

Burst pressure ratings are 1000 psi and 2500 psi.

Write in No. 291 on Reader Service Card

more on page 320

Airborne components that guarantee circuit reliability

In the airborne electronics field—plane, missile or space program—the paramount requirements are: reliability, durability, light weight and small size. Westinghouse combines these product characteristics with engineering talent and breadth of line to offer you an exceptional source for a greater variety of electronic components and subassemblies than any other manufacturer.

Weapons systems like THOR, TITAN, FALCON, TARTAR, BOMARC, and many still classified have specified "Westinghouse" for this reason.

However demanding your requirements may be, your best insurance to protect your circuit designs is the Westinghouse line of high-reliability components. For assistance call your Westinghouse sales engineer or write: Westinghouse Electric Corporation, P.O. Box 868, 3 Gateway Center, Pittsburgh 30, Pa.

WESTINGHOUSE ELECTRONIC COMPONENTS
for projects that must not fail

Control Devices • Instrumentation • Laminated Plastic Forms (Micarta®) • Magnetic Amplifiers • Magnetic Materials • Power Supplies • Static Inverters • Semiconductors • Transformers and Components • Tubes: Cathode-Receiving-Power-Nuclear Control

Write for your copy of the new Westinghouse Electronic Components Design Engineers Handbook.

J-92027

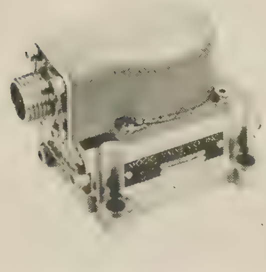
YOU CAN BE SURE...IF IT'S

Westinghouse

WATCH "WESTINGHOUSE LUCILLE BALL-DESI ARNAZ SHOWS" CBS TV FRIDAYS

Write in No. 177 on Reader Service Card at start of Product Preview Section

SERVO VALVES
use simplified design



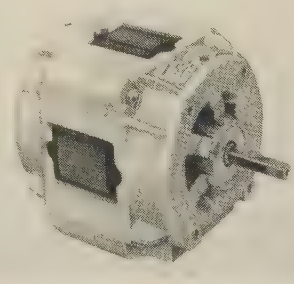
Compactness, low weight, and excellent performance and reliability are offered by the Series 31 and 32 miniaturized electrohydraulic servo valves, says **Moog Valve Co., Inc., Dept. S/A, East Aurora, N.Y.** The units are useful for flight control systems in aircraft and missiles, as well as for a wide range of industrial installations.

The design features a double-nozzle-flapper hydraulic amplifier and internal mechanical feedback from the second stage sliding spool to the first stage torque motor. Flow capacities are available to 16 gpm at 3000 psi, and standard units operate over a —65 to +350-deg F range.

Write in No. 285 on Reader Service Card

INDUCTION MOTOR
is small, with high power

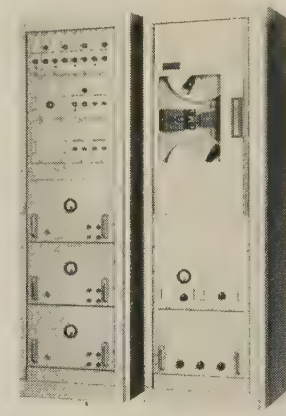
This miniaturized induction motor, model 9200, features magnetic and electric circuits (24/20 slots), sinusoidally distributed windings and internal rotor slotting, resulting in exceptionally quiet operation, low level magnetic hum, reduced external magnetic field, low temperature rise and minimum cogging and hunting, says **Howard Industries, Dept. S/A, 1760 State St., Racine, Wis.** Frame size is 2⅝x2⅞ in with overall length of 4¹⁄₃₂ in for frame 9210 and 4¹³⁄₃₂ in for frame 9214.



It is a permanent split capacitor, single phase, 50/60 cycle motor available in induction, torque and synchronous types. Hp ratings from 1/300 to 1/80.

Write in No. 286 on Reader Service Card

SEVEN-TRACK RECORDER
has one megacycle response



The CV-100 series of instrumentation tape recorders using ½ in. magnetic tape, offers 7 full channels of 1 Mc information, according to **Minnesota Mining & Mfg. Co., Mincom Div., Dept. S/A, 2049 So. Barrington Ave., Los Angeles 25, Calif.**

Tape speed of 120 ips allows 12 min. of running time, using standard 1 mil tape. Peak flutter and wow are 0.1% measured from 0.1 to 4000 cycles.

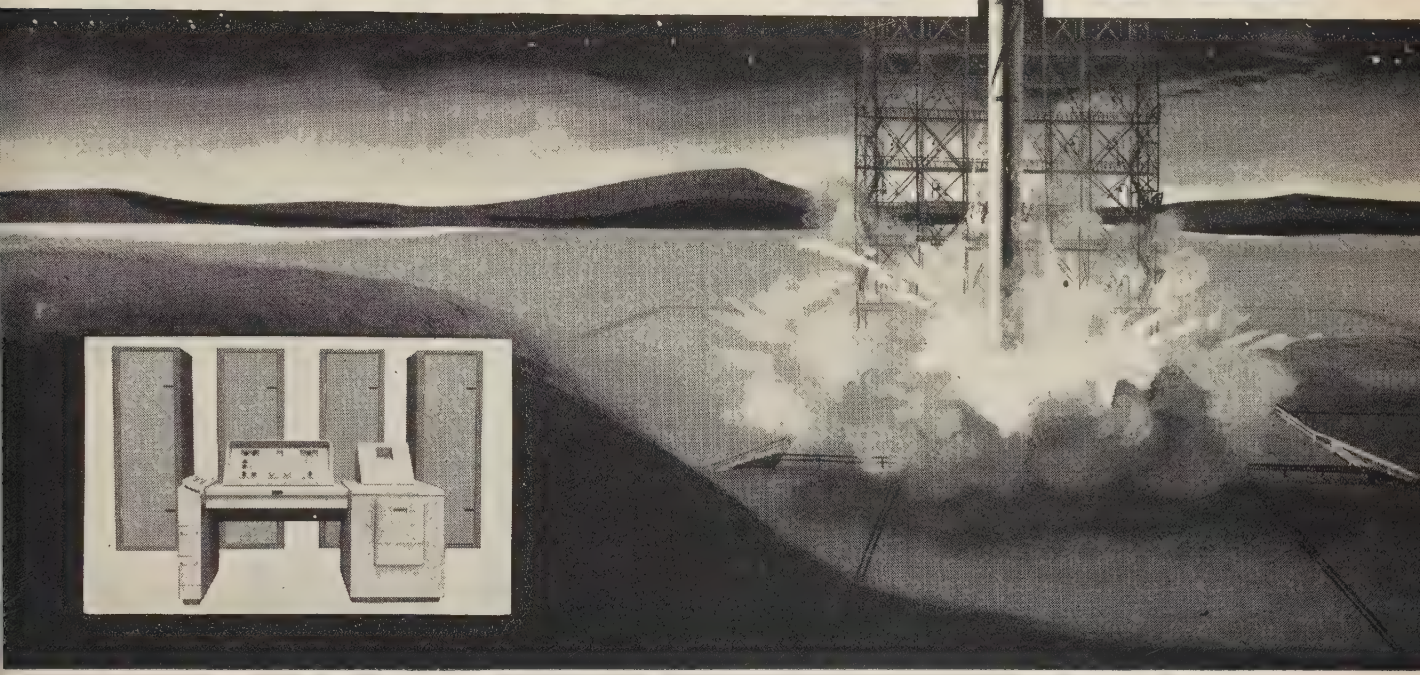
Write in No. 225 on Reader Service Card

more on page 324

APCHE

The Checkout that says "GO" or "NO GO"

(Pronounce "AP-SHE")



APCHE (Automatic Programmed Checkout Equipment) is a solid-state, universal, high-speed, highly reliable, compact general-purpose tester designed especially for automatic checkout of aircraft, missile and space systems and their supporting systems. In its various versions (differing in input media, size and weight) APCHE installations may be fixed, mobile, airborne or submarineborne. APCHE was designed and is being produced as a part of RCA's ground support electronics subcontract from the Convair (Astronautics) Division of General Dynamics Corporation, prime contractor for the ATLAS Intercontinental Ballistic Missile.

The system being supplied to Convair for the ATLAS Program includes a console and four rack cabinets providing both analog and discrete test functions with a resulting printed and GO-NO GO indication. As a product of RCA's Missile Electronics and Controls Department, Burlington, Massachusetts, APCHE is one of the latest RCA developments in the field of military weapon readiness equipments.

RCA **RADIO CORPORATION of AMERICA**

DEFENSE ELECTRONIC PRODUCTS • CAMDEN, NEW JERSEY

Tmk(s) ®

FALCON MISSILE

Playing follow-the-leader at 50 millisecond intervals, three *Super* Falcon missiles rocket ahead of their diamond-shaped supersonic shock waves. Homing in on radar, these deadly air-to-air missiles locate, track, and destroy their prey, with the same killer instinct of the birds they're named after.

Hughes Aircraft, the developer and manufacturer of these missiles and the Armament Control System that triggers them, specified Hitemp magnet and Teflon* wire for their missile, and Teflon wire for its control system.

Hitemp Wires, Inc., the leading specialist in high temperature insulated wires and cables, proudly answers roll call with those developers and manufacturers enlisted in defending our American birthright—*Freedom.*

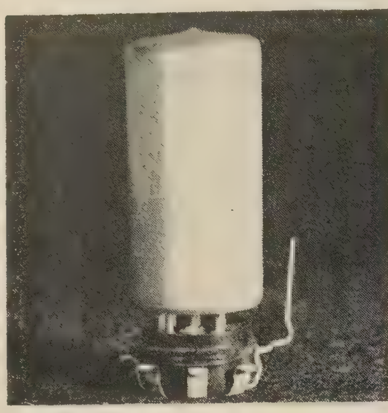
HITEMP WIRES, INC.

1200 SHAMES DRIVE, WESTBURY, NEW YORK

*Registered trademark for Du Pont fluorocarbon resins.

Write in No. 237 on Reader Service Card at start of Product Preview Section

MICRO CHOPPER is photo-electric type



Model PEMC-1 Photo-Electric Micro Chopper consists of 2 photoconductive cells and one gas-discharge lamp. The unit operates from 0 to 20 kcps and has a life expectancy greater than 3000 hrs, says **Titan Eng. Corp., Dept. S/A, 921 Orangethorpe Pk., Anaheim, Calif.**

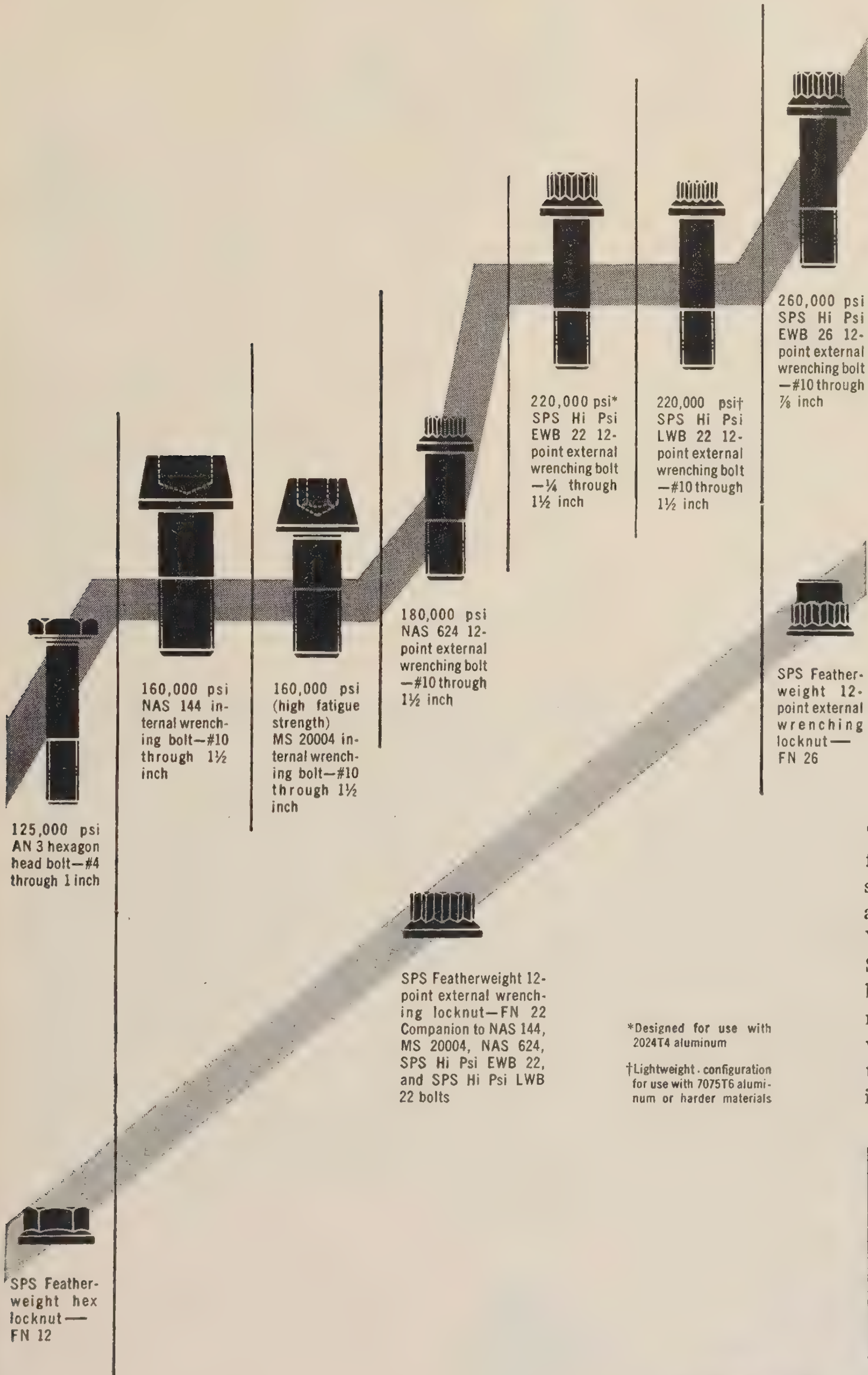
The chopper has no moving parts and is hermetically sealed and potted. The unit operates from 115 V from −50 deg to +100 deg C and requires 0.3 watts. It weighs about 10 oz and measures 1½ in. long by ¾ in. in diam.

Write in No. 457 on Reader Service Card

more on page 328

Just name the tensile strength...

SPS offers a tension bolt and companion locknut for every application up to 260,000 psi



*Designed for use with 2024T4 aluminum

†Lightweight configuration for use with 7075T6 aluminum or harder materials

Tension bolts and locknuts shown (a fraction of the complete SPS line) are serviceable to 550°F. Other fasteners are available for service through 1600°F. Whatever your particular requirements, SPS can offer a bolt and locknut combination certified for high mechanical reliability. For complete information, write SPS—manufacturer of precision threaded fasteners and allied products in many metals, including titanium.

AIRCRAFT / MISSILE Division SPS

JENKINTOWN 54, PENNSYLVANIA

SPS WESTERN, SANTA ANA, CALIFORNIA

Write in No. 239 on Reader Service Card at start of Product Preview Section

Mission: **LUNAR PROBE**

Filter application: **PROTECT HYDRAULIC CONTROLS**

Filter choice: **PUROLATOR**

Complex, "must-succeed" filter applications in Atlas and other top priority projects are some of the tough new space-age filtration problems our engineers have solved. Your call or letter will put their unique experience and production facilities at your disposal, to help you develop ways of handling your own aircraft and missile filtration requirements.

Filtration For Every Known Fluid

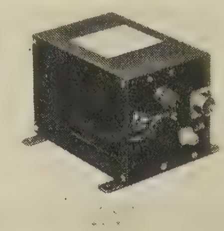
PUROLATOR

PRODUCTS, INC.

Rahway, New Jersey and Toronto, Ontario, Canada

Write in No. 226 on Reader Service Card at start of Product Preview Section

ALTITUDE CONTROLLER has two operational modes

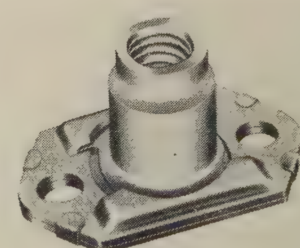


A high degree of accuracy under missile and aircraft environments is claimed for this dual-mode barometric altitude controller by **General Controls Co., Dept. S/A, 801 Allen Ave., Glendale 1, Calif.** In unengaged operation, the instrument provides instantaneous altitude or pressure information as a voltage and shaft position; in the engaged mode, it offers data on altitude deviations for flight control use.

Standard operating range for the 43-oz controller extends to 100,000 ft, and temperature errors are held to plus or minus three ft between —55 and +71 deg C. Along the sensitive axis, vibration and shock effects are less than one ft per g. In the unengaged mode, linearity and hysteresis are held to ±0.25 per cent or 100 ft, up to 80,000 ft. For engaged operation, linearity over ±500 ft excursion is plus or minus three per cent and hysteresis is under three ft upon return to engage altitude.

Write in No. 459 on Reader Service Card

FLOATING NUTS are stainless steel



This miniature floating spacer nut made in counter bore depths from ⅛ in. through ⅜ in. 1/16 increments, eliminates shims. Reluction in weight and increased speed of installation is claimed for them, according to **Nutt-Shel Co., Dept. S/A, 2701 S. Harbor Blvd., Santa Ana, Calif.** They are available in 10-32 ¼-28 and 5/16-24 thread sizes.

Series No. M13701, conforming to NAS 1068, except for height, is made in stainless steel. Both miniature and standard floating spacer nuts conform to MIL-N-25027.

Write in No. 460 on Reader Service Card

more on page 330

Check Employment Inquiry Form on Page 217

These R&D Projects for Future Decades in Space

typify Lockheed's vast program of Air/Space Science

■ New programs under development at Lockheed's California Division are planned to solve America's future exploration projects into space. The new multimillion-dollar Research Center in nearby San Gabriel mountains is further evidence of Lockheed's determination to support and supplement its already extensive research and development activities.

As a result of this markedly expanded program, there is urgent need for engineering and scientific personnel with high-level technical skills.

Long a leader in advancing the science of flight, Lockheed is placing vast resources and accumulated knowledge into programs designed to provide major breakthroughs in the fields of: Basic and applied research; manned aircraft of advanced design; missiles and spacecraft. Some of these important research and development programs are:

High Altitude Flight Vehicles with speed ranges between Mach 8 and 25. Problems associated with landing **Manned Space Vehicles** capable of hypersonic glide or orbit about the earth. **Infrared System** studies as an advanced method of detecting ultrasonic missiles and high-speed aircraft. **Solar Radiation** studies. **Vertical Take-Off and Landing** and "air recovery" vehicles. **Helicopters. Supersonic Transports.**

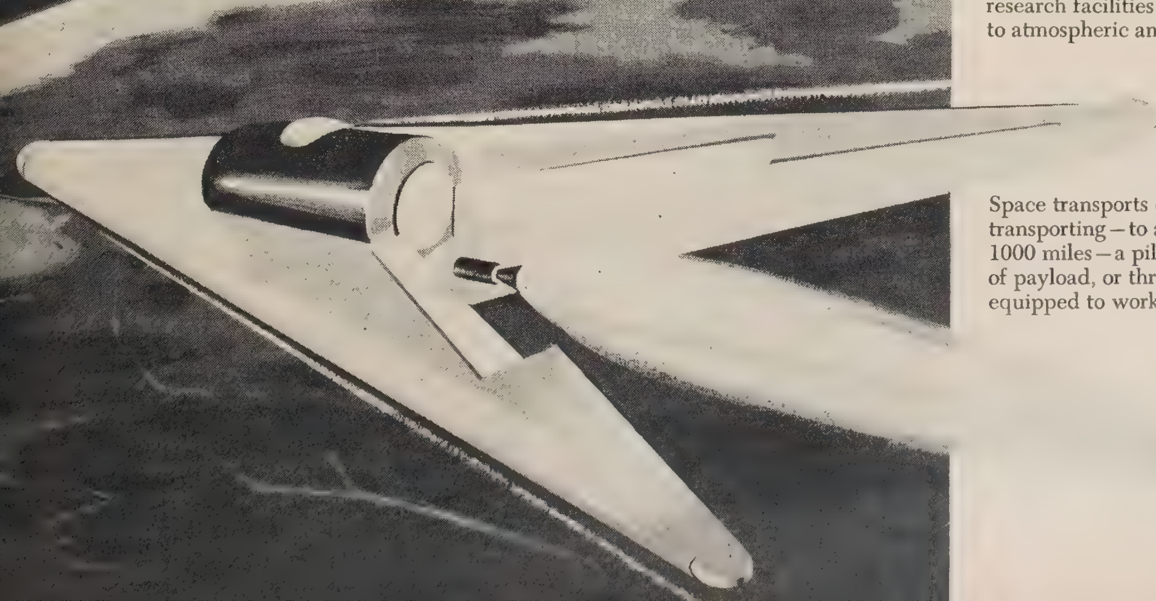
High caliber scientists and engineers are invited to investigate Lockheed's outstanding career opportunities. Openings now exist in: Aero-thermodynamics; propulsion; armament; electronics—research and systems; servomechanisms—flight controls; sound and vibration; operations research; physics; antenna and telemetry; underwater sound propagation; and for engineers with experience in structural, electrical and mechanical design.

Write today to: Mr. E. W. Des Lauriers, Manager Professional Placement Staff, Dept. 1911, 2400 North Hollywood Way, Burbank, California.

LOCKHEED

CALIFORNIA DIVISION
BURBANK, CALIFORNIA

New Multimillion-Dollar Research Center under construction in Southern California's San Gabriel Mountains—designed to house most of the research facilities of Lockheed's California Division. Here will be found advanced research facilities in all fields related to atmospheric and space flight.



Space transports capable of transporting—to an orbit of more than 1000 miles—a pilot and 1000 pounds of payload, or three passengers equipped to work in space.

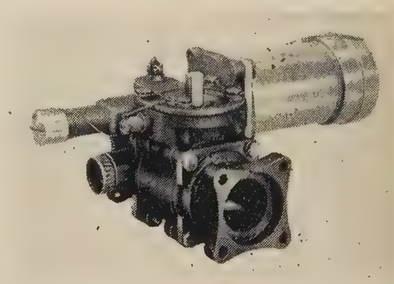
ALKYD COMPOUND *is flame-resistant*

This glass fiber reinforced alkyd molding compound, Glaskyd 2051, designed for military applications, is classified as an MAI-30 material, covered by specification MIL-M-21699. Meant for flame resistance, good strength and excellent electrical properties and moldability, typical applications are electrical parts such as circuit breakers, switch housings, terminal boards, connectors, fuse holders and rotary switches.

It is a free flowing material and is produced and packaged in continuous rope form in diameters from ½ in to 1¼ in.

Write in No. 461 on Reader Service Card

VALVE *for hydrazine fuels*



A missile fuel valve specifically constructed to handle hydrazine fuels in the —35 to +120-deg F range, at line pressures of 220 psi, has been developed by **Koehler Aircraft Products Co., Dept. S/A, 409 Leo St., Dayton, O.** The helium-powered actuator is effective over a —100 to +300-deg F range and at 250 psi.

Time from full-open to full-closed takes .030 sec maximum, a characteristic useful in aircraft, missile and rocket applications.

Write in No. 462 on Reader Service Card

SILICON RECTIFIERS *in high-voltage series*

Four new high-voltage, high-current silicon rectifiers have been announced by **Pacific Semiconductors, Inc., Dept. S/A, 10451 W. Jefferson Blvd., Culver City, Calif.** The units are said to provide higher current ratings, lower forward voltage drop, and better reverse leakage characteristics than previously available types.

EIA type numbers 1N2382 through 1N2385 have ratings of 4000, 6000, 8000 and 10,000 V PIV; at 25 deg C, maximum rectified current is 150, 100, 70 and 70 ma, respectively. The nonmetallic housing used has a 400 V/mil dielectric strength and a resistivity of over 10^{14}ohm-cm. All four units are ½ in in dia and vary in length from one to two in, depending on voltage rating.

Write in No. 463 on Reader Service Card

more on page 334

DELCO RADIO

NEW POWER TRANSISTORS

MILITARY–COMMERCIAL

	2N1168	2N392	2N1011	2N1159	2N1160
V_{cb} max.	50	60	80	80	80 volts
I_c max.	5	5	5	5	7 amp.
I_{co} (V_{ec} 2 volts) Typical 25°C.	65	65	65	65	65 μa.
HFE (3 amp.)	—	60-150	30-75	30-75	—
HFE (5 amp.)	—	—	—	—	20-50
AC Power Gain (I_c=0.6 amp.)	37 DB	—	—	—	—
V_{ceo} (I_c = 1 amp.)	40 typical	50 typical	60 min.	60 min.	60 volts min.
Thermal Gradient max.	1.5	1.5	1.2	1.2	1.2° c/w

Delco Radio rounds out its power transistor line with this new 5-ampere germanium PNP series. Types 2N1168 and 2N392 are specially designed for low-distortion linear applications, while 2N1159 and 2N1160 are outstanding in reliable switching mode operations.

Type 2N1011 is designed to meet MIL-T-19500/67 (Sig. C). It joins 2N665, MIL-T-19500/68 (Sig. C); 2N297A, MIL-T-19500/36 (Sig. C) and JAN2N174, MIL-T-19500/-13A to provide a selection for military uses.

Write today for engineering data on Delco Radio's line of High Power Transistors.

DELCO RADIO

DIVISION OF GENERAL MOTORS
KOKOMO, INDIANA

BRANCH OFFICES

Newark, New Jersey
1180 Raymond Boulevard
Tel: Mitchell 2-6165

Santa Monica, California
726 Santa Monica Boulevard
Tel: Exbrook 3-1465

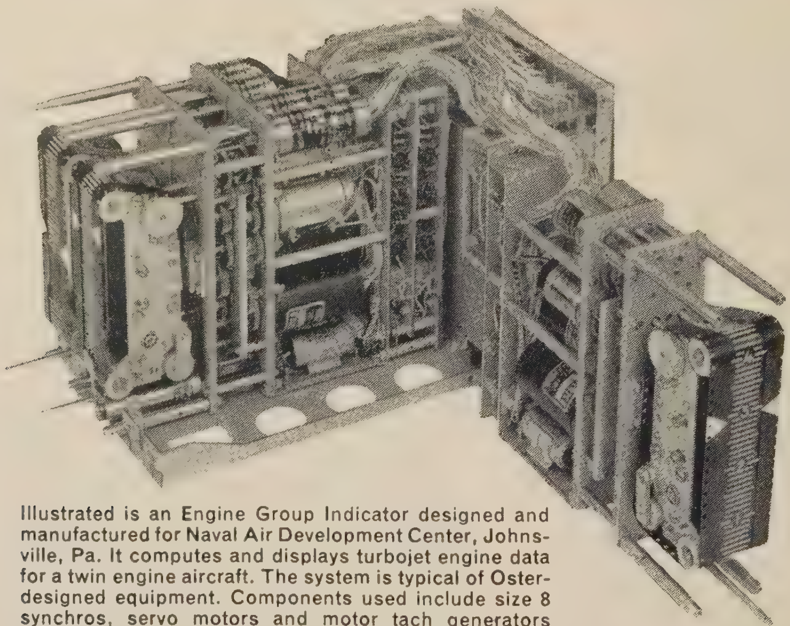
Write in No. 186 on Reader Service Card at start of Product Preview Section

B-70 TRIPLESONIC GLOBAL BOMBER *to use* OSTER POWER PLANT INSTRUMENT SUBSYSTEM

Oster®

Management responsibility under the weapon system concept has been delegated to John Oster Manufacturing Co., Avionic Division, for the design and manufacture of the Air Force B-70 power plant instrumentation subsystem.

For this, the Avionic Division is drawing heavily on its experience in the fields of engine performance analysis, engine parameter measurement, hi temp engine mounted transducers, electromechanical analog computer design, data display systems, indicator design and integral lighting.



Illustrated is an Engine Group Indicator designed and manufactured for Naval Air Development Center, Johnsville, Pa. It computes and displays turbojet engine data for a twin engine aircraft. The system is typical of Oster-designed equipment. Components used include size 8 synchros, servo motors and motor tach generators manufactured by Oster.

Note unusual electrical and mechanical design. If tackling problems like this interests you, contact Mr. Robert Burns in confidence.

For help with your instrumentation and display problems, talk to the specialists at the Avionic Division.

OTHER PRODUCTS INCLUDE:

- Servos
- Synchros
- Resolvers
- Motor Tachs
- DC Motors
- Computers
- Indicators
- Servo Mechanisms
- Servo Torque Units

John Oster MANUFACTURING CO.
Specialists in Instrumentation and Display
Avionic Division
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Engineers For Advanced Projects: Interesting, varied work on designing transistor circuits and servo mechanisms.
Contact Mr. Robert Burns, Personnel Manager, in confidence.

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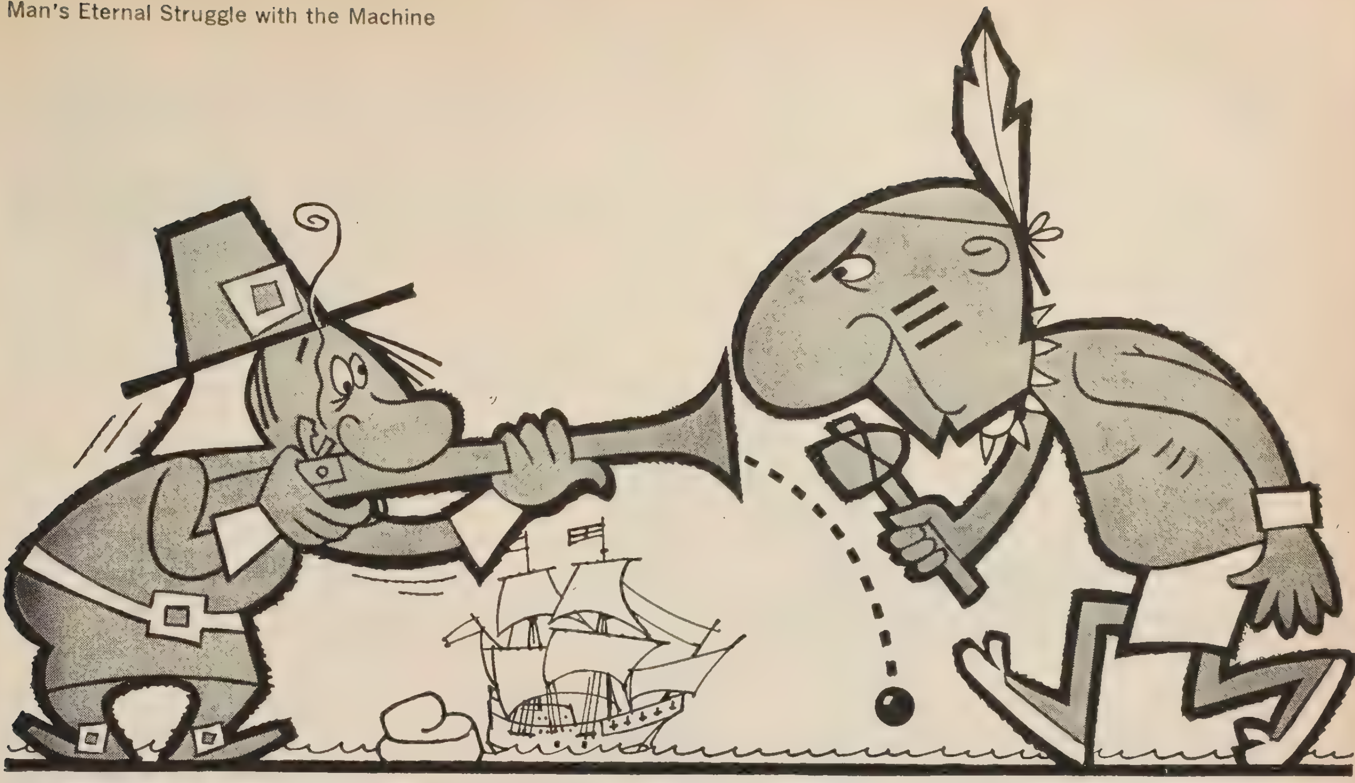
BURTON BROWNE ADVERTISING



RISING COSTS AND SHRINKING PROFITS EXERT UNUSUAL PRESSURES ON PROCUREMENT

What is the risk of letting conditions tempt you to select the lowest bid?

You're in a tough spot to say the least!

Because if you care at all about *your* future or your company's profits, you take every precaution to make sure that "real deal" price tag is hanging on a machine that *will* do your job.

Obviously, price alone is indicative of nothing more than the bidder's determination of cost, plus the profit any manufacturer must earn to remain in business—nothing more—no true suggestion of value . . . and, of course, never even a hint of equipment suitability to *your* needs.

Unfortunately, the lowest bid often results from price cutting under competitive pressures. And price cutting *necessarily* down grades equipment value—unless the price-cutter is in business for reasons other than making a profit!

Sciaky resistance welding and production equipment *must* satisfy *your* manufacturing requirements. And Sciaky manufacturing operations must earn a profit just as your company must. That's why Sciaky *first* determines what *will* satisfy your requirements, and then figures the cost of putting it to work for you.

Why take less than the full advantage of consulting with a Sciaky Application Engineer the next time you are considering equipment. No obligation, of course.

Recently a procurement official boasted of his subterfuge to reduce costs . . . "tell every vendor his bid is way out of line, and you can brow-beat them into substantial price reductions." Besides the question of ethics, he's cheating his company of its ability to manufacture profitably, as well. Because no vendor can deliver more than he gets paid for—that is, not if he intends to stay in business. When that official's manufacturing operations begin to sag under the dead weight of phony equipment bargains, who do you suppose is going to be holding the proverbial bag?

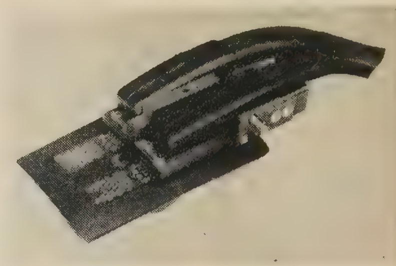
SCIAKY

70A

SCIAKY BROS., INC., 4912 W. 67th STREET, CHICAGO 38, ILLINOIS • POrtsmouth 7-5600

Write in No. 245 on Reader Service Card at start of Product Preview Section

UMBILICAL for missile use

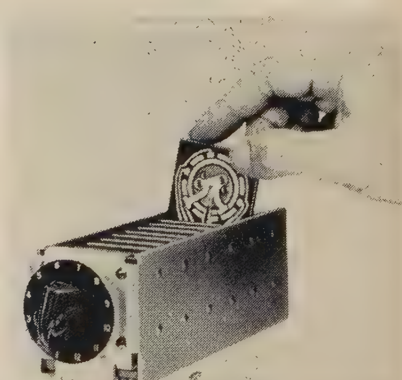


This Electrical Umbilical design has 126 pins (4 through 20 contact size) with spring leaf contacts (no pin friction) and two ½" water methanol electronic cooling lines for the guidance package, says **E. B. Wiggins Oil Tool Co., Inc., Dept. S/A, 3424 Olympic Blvd., Los Angeles 23, Calif.**

Other features: lanyard disconnection and cam retraction of the connector as a function of missile motion; unit is integral to the missile skin and forms a part of the stress bearing structure; connecting surface is electrically isolated upon disconnect; cabling integrated into single component with the electrical insert making maintenance simple; surface of missile half is flush within 0.030; and electrical connector can be submerged in salt water in the connected condition without electrical or mechanical failure.

Write in No. 464 on Reader Service Card

ROTARY SWITCH for quick replacement



This rotary switch, any wafer which lifts out instantly without unsoldering or disassembling, allows instant replacement. Replacements are said to be error-proof and no wires need to be removed, according to **Chicago, Dynamic Industries, Inc., Dept. S/A, 1725 Diversey Blvd., Chicago 14, Ill.** Switches are available in sizes approx 2x2 in, 3x3 in and 4x4 in with lengths to accommodate up to 36 wafers.

Switches may be manually, motor or solenoid operated for use in any rotary selector switch application.

Write in No. 465 on Reader Service Card

more on page 336

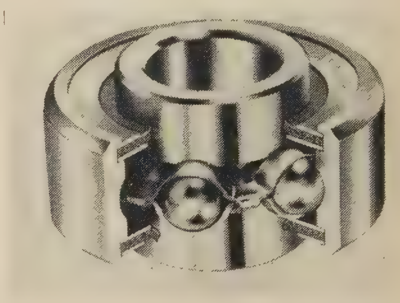
SILICONE RUBBER WIRES for high temperatures

This lead and hook-up wires and aircraft and circuit wires insulated with silicone rubber is available in AWG sizes 4 through 28 an temperature ranges of −55 deg C to +200 C, according to **American Super-Temperature Wires, Inc., Dept. S/A, W. Canal St., Winooski, Vt.** They meet Navy MIL-W-16878C, type F for 600v service, and type FF for 1000v service, and MIL-W-8777A.

Protective jackets can be fabricated in teflon impregnated fiberglass, nylon, dacron, or mixtures of them.

Write in No. 466 on Reader Service Card

SEALED BEARINGS high speed aircraft



These high temperature, low-torque, sealed ball bearings for high speed aircraft, designated the AW-AK series, were designed for sensitive aircraft control. They are fabricated of stainless steel, heat-stabilized, and lubricated with heat resistant oil, says **Fafnir Bearings Co., Dept. S/A, New Britain, Conn.** Available with teflon fabric seals that withstand temperatures in the 550 deg range.

These seals are said to hold seal drag to a minimum.

Write in No. 467 on Reader Service Card

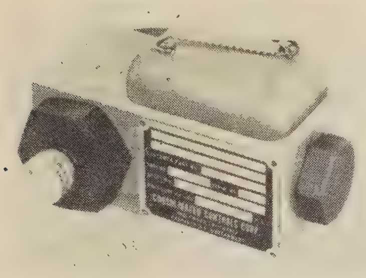
POTENTIOMETER has long life

The Model 55, a wire-wound precision potentiometer that has been vibration-tested for up to 24 g at 500 cps and up to ten g at 1000 cps, is available in servo-mounting packaging or standard bushing mount, according to **New England Instrument Co., Dept. S/A, 320 Main St., Woonsocket, R.I.** It has a trouble-free life expectancy of five million revolutions in certain combinations of service conditions.

Standard units have a maximum resistance of 100 k, plus or minus five per cent, and plus or minus one per cent on special types. The potentiometer is rated for two W at 65 deg C, and ambient temperature range is −55 to +105 deg C for standard types.

Write in No. 468 on Reader Service Card

PRESSURE SWITCH has poppet-type action



This differential pressure switch with poppet-type action is used to measure pressure differences between two locations in a hydraulic or pneumatic circuit and, at a predetermined difference, to close or open an electrical circuit, operating an alarm or a control device, says **Consolidated Controls Corp., Dept. S/A, 750 So. Isis Ave., Inglewood, Calif.** A typical application is the sensing of pressure drop across filters, an indication of the degree of contamination of the filter element.

A spring is preloaded against a poppet, seating the poppet against the higher of the two pressures being sensed. When the spring preload is exceeded, the poppet moves from its seat, exposing an even greater area to the high pressure. This causes the poppet to snap to a second position, which operates the one or two micro-switches in the unit.

Write in No. 469 on Reader Service Card

TOROIDAL INDUCTORS have wide range

Series 783, miniature toroidal inductors have a useful frequency range from 10 Kcps to 500 Kcps. Inductance values of the units range from 1mh to 3h, says **Arnold Magnetics Corp., Dept. S/A, 4613 W. Jefferson Blvd., Los Angeles 16, Calif.**

The units measure 1 in. diameter by ½ in. high and weigh only 0.5 oz. These inductors are designed with a 6-32 threaded insert for printed circuits. Built to meet MIL-E-5272A and MIL-T-27-A, the units are fully encapsulated and hermetically sealed.

Write in No. 470 on Reader Service Card

data preview

MOTOR-GENERATOR — A 16-page technical brochure describing the characteristics of a series of motor-tachometer generators has been issued by **Avionic Div., John Oster Mfg. Co., Dept. S/A, 1 Main St., Racine, Wis.** Catalog 6000 covers units from Size 8 through 18.

Write in No. 471 on Reader Service Card

OSCILLOGRAPH—Up to fifty channels of test data on a 12-in wide record may be recorded by the Model 603 direct recording-readout oscillograph, according to information released by **Midwestern Instruments, Dept. S/A, P.O. Box 7186, Tulsa, Okla.** Record speeds are variable from .05 to 170 ips, and trace writing capability exceeds 30,000 ips.

Write in No. 472 on Reader Service Card

TIEDOWN RING—A brochure briefly describing tiedown rings of 25,000-, 10,000- and 5000-lb capacity has been released by **Puritas Metal Products Co., Dept. S/A, 16116 Puritas Rd., Cleveland 35, O.** The folder also illustrates a hold-down trailer chassis clamp.

Write in No. 473 on Reader Service Card

WIRING TOOLS—Rapid-Wrapit tools, which are hand-operated tools for making solderless, wrapped wire connections, have been described in an illustrated four-page brochure by **Utica Drop Force & Tool Div., Kelsey-Hayes Co., Dept. S/A, Utica 4, N. Y.** Connections made with the tools are said to be stronger, more uniform and less expensive than conventionally soldered connections.

Write in No. 474 on Reader Service Card

RELAYS—LRD-CC-59 is a four-page brochure that presents specifications and ratings of crystal can relays made by **Leach Corp., Dept. S/A, 5915 Avalon Blvd., Los Angeles 3, Calif.** The subminiature units can meet stringent environmental requirements in control system, computer, aircraft, missile, and other other applications.

Write in No. 475 on Reader Service Card

METAL STAMPINGS—A four-page brochure on precision drawn closures and metal stampings, including covers, cases, and subassemblies, has been prepared by **Hudson Tool & Die Co., Inc., Dept. S/A 18-38 Malyern St. Newark 5, N. J.** The illustrated publication points out that over 1600 standard can sizes are made in eight metals.

Write in No. 476 on Reader Service Card

CERAMICS—The mechanical and electrical properties of high strength alumina ceramics suitable for use in missile applications, among others, have been tabulated in four-page Bulletin 858 by **Coors Porcelain Co., Dept. S/A, 600 Ninth St., Golden, Colo.** Production techniques and precision and metalizing facilities for ceramic parts manufacture are briefly described.

Write in No. 477 on Reader Service Card

CHEMICAL MILLING—Advances in the art of chemically milled steel alloys are described in design bulletin No. 8 by **U. S. Chemical Milling Corp. Dept. S/A, 1700 Rosecrans Ave., Manhattan Beach, Cal.** It is prepared for designers as well as production engineers concerned with uses of steel alloys.

Write in No. 478 on Reader Service Card

LOCKNUTS—Locknuts having high strength and lightweight for use in aircraft missile and relation applications at temperatures up to 1200 deg are described in Form 2468 by **Standard Pressed Steel Co., Dept. S/A, Box 879, Jenkintown, Pa.** Photos, design drawings and charts are included.

Write in No. 479 on Reader Service Card

CABLE—Low pickup, minimum radiation inter-8 cable are described in data sheet C-1 by **Perfection Mica Co., Dept. S/A, 1322 N. Elston Ave., Chicago 22, Ill.** It shows present test data, external field pickup test and applications.

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ACCESSORY EQUIPMENT—An illustrated catalog describing accessory equipment for use in aircraft, missile and space craft has been issued by **Lyndon Aircraft, Inc., Dept. S/A, 140-15 Clifford St., Newark 5, N. J.** It contains accessory description, application, engineering data, performance curves and dimension drawings.

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STRUCTURAL PARTS — Production processes for structures, sub-assemblies and other components for missiles, rockets, aircraft, marine and general industrial applications are described in a brochure by **Prewitt Aircraft Corp., Dept. S/A, Madison & Holley Sts., Clifton Heights, Pa.** Included are a pressurized battery box of reinforced plastic and an asbestos-phenolic nose cone for missiles.

Write in No. 482 on Reader Service Card

PRESSURE SYSTEMS — Descriptions and illustrations of standard and accessory high pressure items, as well as custom-built super-pressure equipment are contained in catalog 407 by **American Instrument Co., Dept. S/A, 8030 Georgia Ave., Silver Springs, Md.** It has detailed information on reaction vessels and other applications.

Write in No. 483 on Reader Service Card

EXPANSION JOINTS—A complete line of packless corrugated expansion joints are described in a bulletin by **Zallea Brothers, Dept. S/A, 815 Locust St., Wilmington 99, Del.** Application aids are included.

Write in No. 484 on Reader Service Card

OXYGEN TESTING—Gaseous oxygen testing of air and spaceborne components and systems is described in a brochure by **Telecomputing Corp., Whittaker Controls Div., Dept. S/A, 915 N. Citrus Ave., Los Angeles 38, Cal.** Calibration of high-capacity mass flow meters is explained, and testing in a wide range of environmental functional conditions which reproduce actual in-flight operations.

Write in No. 485 on Reader Service Card

WELDING—A catalog of welding products has been combined with a guide to practices in a brochure by **Arcos Corp., Dept. S/A, 1500 S. 50th St., Philadelphia, Pa.** It describes stainless, low-alloy, non-ferrous rods and electrodes for manual, automatic and semi-automatic welding.

Write in No. 486 on Reader Service Card

FUEL FILTERS—An engineering data sheet No. 102 describing No. 565383 replacement elements for aircraft main fuel line filters has been prepared by **Bendix Aviation Corp., Filter Div., Dept. S/A, 434 W. 12 Mile Rd., Madison Heights, Mich.** Flow-rate pressure drop curves and cross-section drawings are included.

Write in No. 487 on Reader Service Card

SWITCHES—High temperature switches and metal enclosed, environment-free switches as well as popular types of phenolic-cased, push-button, toggle and integral-actuator types are described in catalog No. 159 by **W. L. Maxson Corp., Unimax Switch Div., Ives Road, Wallingford, Conn.** Also contained are drawings, descriptions, force and movement specification tables and ratings.

Write in No. 488 on Reader Service Card

more on page 340

DATA PREVIEW

MECHANICAL HARNESSING—An engineering design manual, 210G, describes standard clamps, line supports, brackets, and shims in a variety of shapes and sizes prepared by **TA Mfg. Corp., Dept. S/A, 4607 Alger St., Los Angeles 39, Cal.** Included are installation techniques and weight charts.

Write in No. 489 on Reader Service Card

MULTI-CONDUCTOR CABLE—Thermo-Cable, a new type of polyvinyl-insulated, multi-conductor cable for installing 6 to 56 pairs of thermocouple loads at one time, is described and illustrated in Catalog 33 by **Thermo Electric Co., Inc., Dept. S/A, Saddle Brook, N. J.** Charts show specifications, and other tables are included.

Write in No. 490 on Reader Service Card

TEST EVALUATION SYSTEM—A 6-page brochure describing a "Slip-Sync System" for visual and photographic study of vibration tests which will display and/or photograph any repetitive motion has been prepared by **Chadwick-Helmuth Co., Dept. S/A, 472 E. Duarte Road, Monrovia, Calif.** The theory of operation is included.

Write in No. 491 on Reader Service Card

more on page 342

FIRE SYSTEMS—A booklet coverin products designed primarily for air craft and missile applications, fron fire detection and extinguishing equip ment to pneumatic systems and com ponents has been prepared by **Walte Kidde & Co., Aviation Div., Dept S/A, Belleville 9, N. J.** Reinforce plastic fiberglass shapes and form are included.

Write in No. 492 on Reader Service Car

SEALING FASTENERS — Single-unit high-pressure seals and fastener suitable for military, commercial an industrial applications are discusse in Catalog No. 359 by **A.P.M. Corp Dept. S/A, 252 Hawthorne Ave Yonkers, N. Y.**

Write in No. 493 on Reader Service Car

QUICK-RELEASE PIN—An engineerin bulletin of dimensions, specification and call-outs for positive lockin quick-release pins has been prepare by **General Fastener Corp., Dep S/A, P. O. Box 608, Burbank, Cali** Both single and double acting type are covered.

Write in No. 494 on Reader Service Car

MACHINING—An aluminum machin ing chart, Sec. G., No. 2, having table of recommended speeds and feeds f six machining operations has bee prepared by **Peter A. Frasse & Co Inc., Dept. S/A, 17 Grand St., Ne York 13, N. Y.** Sec. E. No. 1 identifi carbon steel government specific tions.

Write in No. 495 on Reader Service Ca

INDUCTORS—Detailed technical da on Series 781 miniature toroidal i ductors are discussed in a data shee prepared by **Arnold Magnetics Corp Dept. S/A, 4613 W. Jefferson Blv Los Angeles 16, Calif.** Plug-in desig is for use in printed circuits.

Write in No. 496 on Reader Service Ca

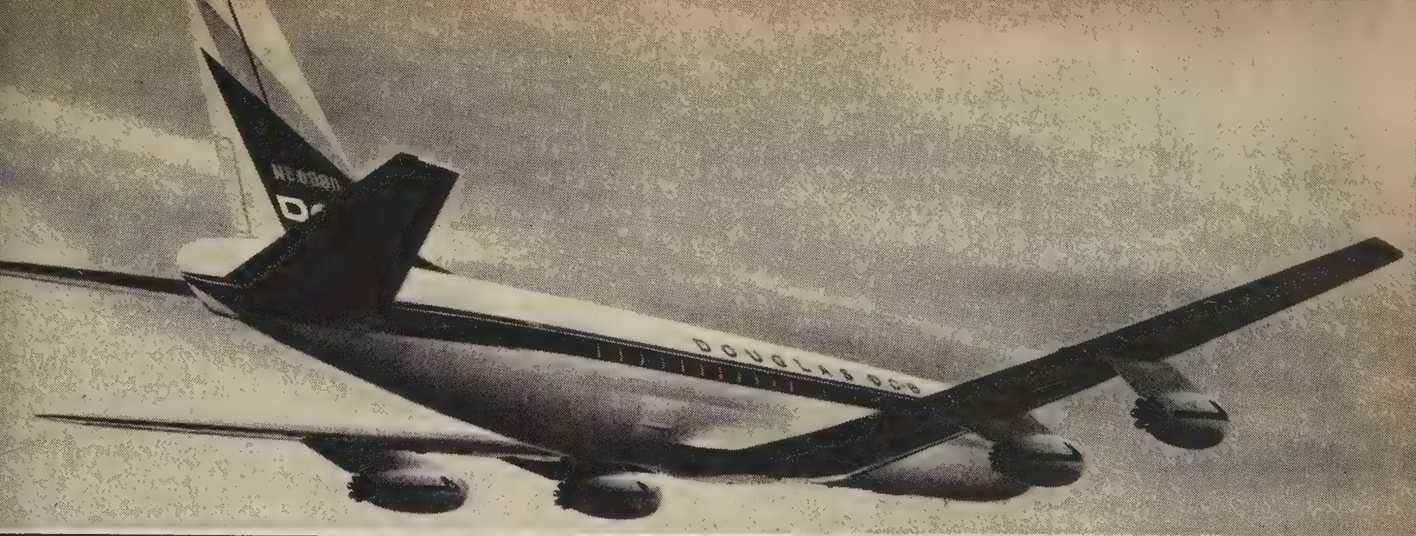
METAL INSPECTION—A method f locating invisible defects in ferro metal parts and assemblies is d scribed in Bulletin F-59 by **Fer Machine & Tool Corp., Dept. S/ 5514 W. Washington St., Indianapol 41, Ind.** The system is said to loca discontinuities.

Write in No. 497 on Reader Service Ca

GAS TURBINES—Aircraft gas turbin designed primarily for helicopters, a discussed in Bulletin 3841 by **Ge eral Electric Co., Dept. S/A, Schene tady 5, N. Y.** Included are results the 150-hour model tests on the T5 GE-6 production engine.

Write in No. 498 on Reader Service Ca

more on page 34



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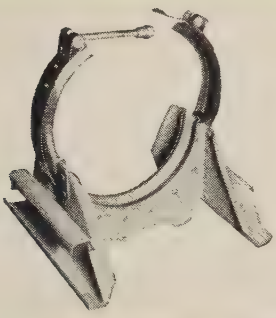
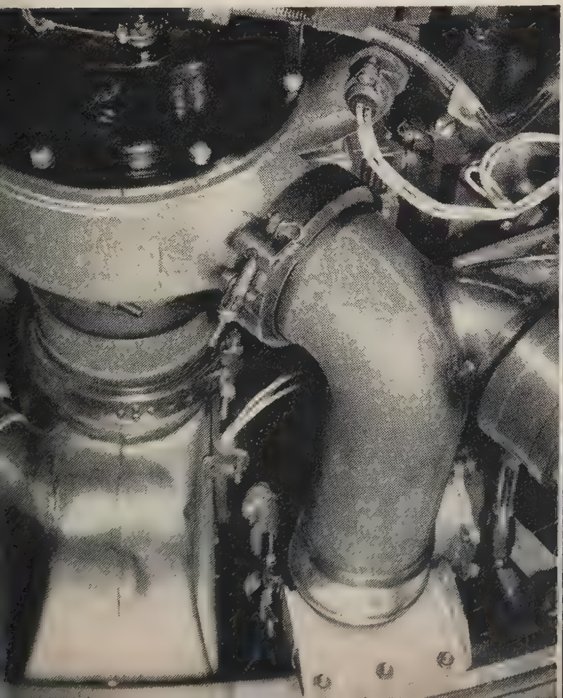


Step aboard United Air Line's new Douglas DC-8 Jet Mainliners with complete confidence that every component has been performance proved. Inside the mighty structures are scores of Janitrol couplings linking vital high pressure air ducts. Only top quality products are used in the DC-8's. Write for the comprehensive booklet, "Janitrol Resources," which documents the capabilities and facilities behind Janitrol quality products. Janitrol Aircraft Division, Surface Combustion Corporation, 4200 Surface Road, Columbus 4, Ohio.



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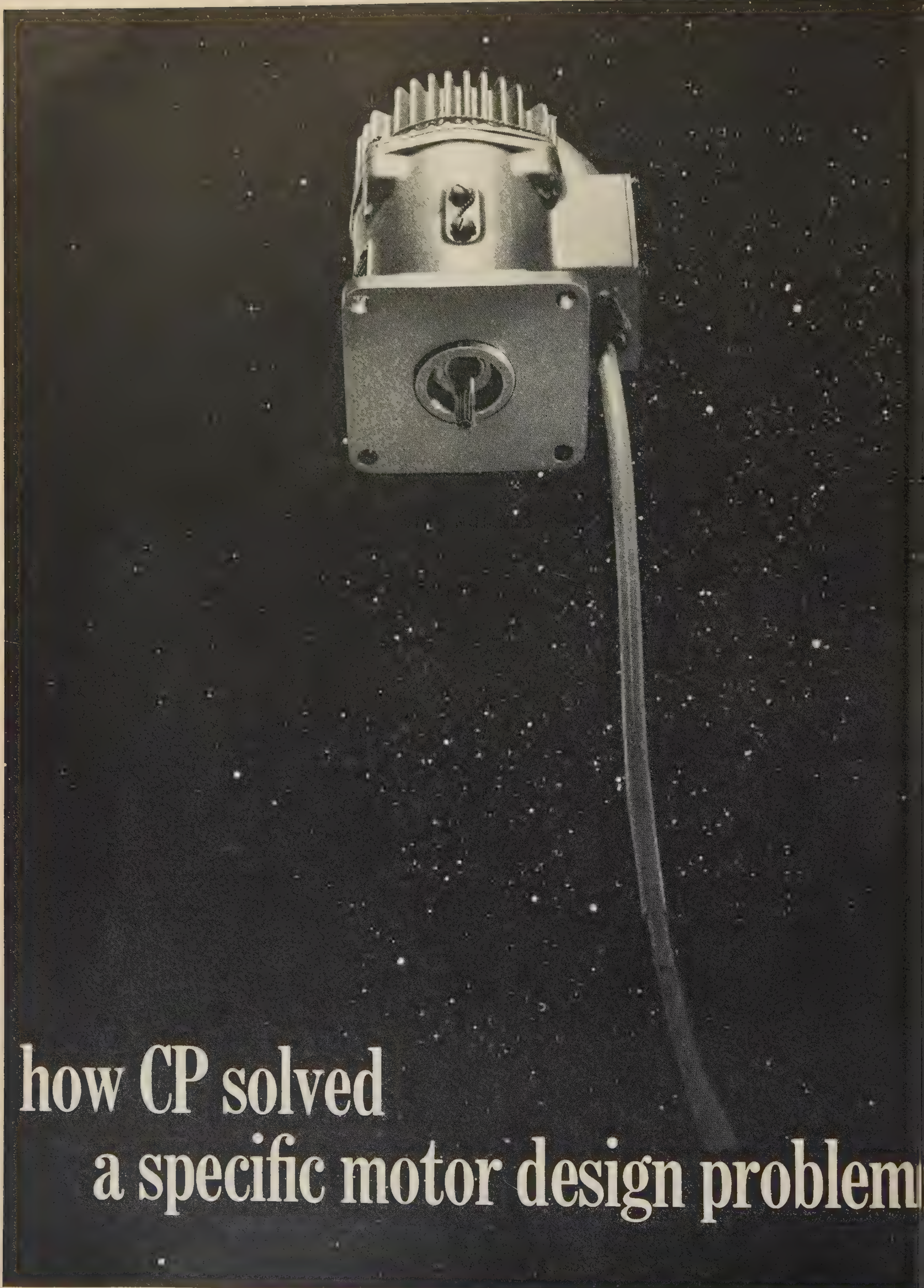

how CP solved
a specific motor design problem

PROBLEM
of Aircraft Component Supplier

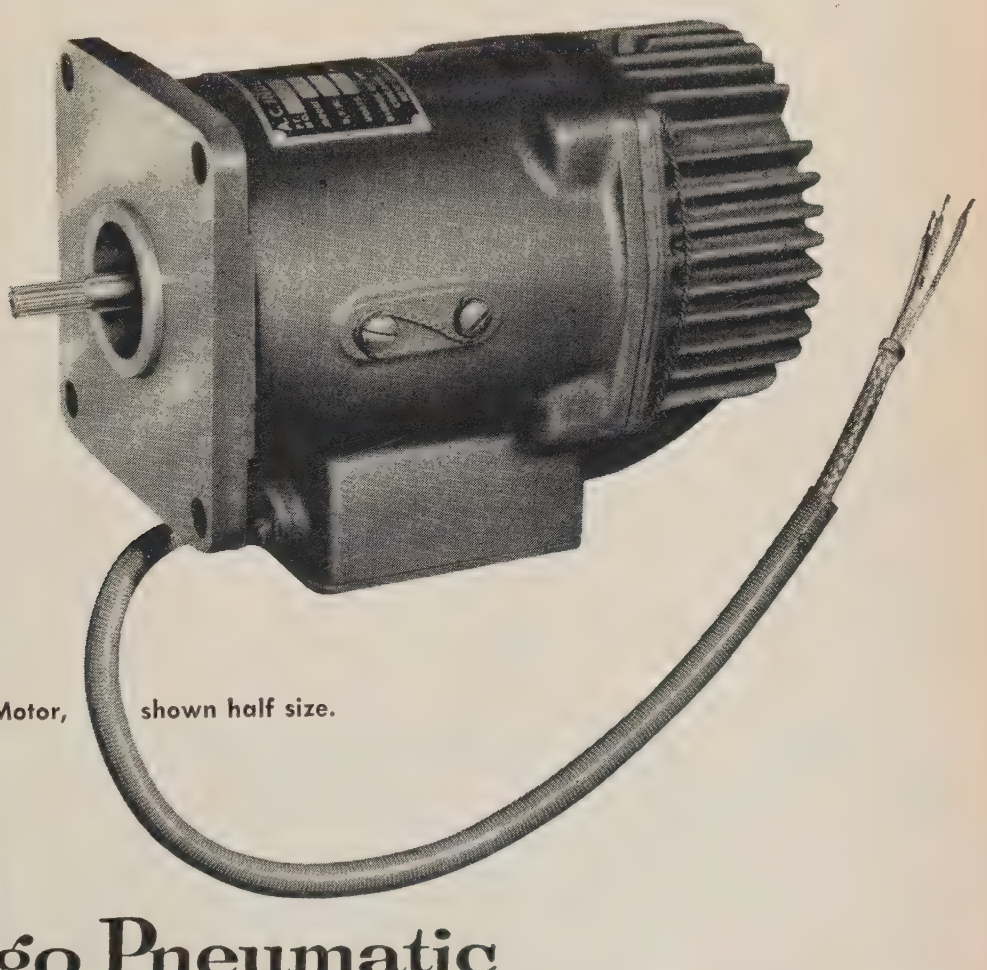
Obtain a motor that would . . .

1. Drive a linear type actuator for automatic pilot controlled elevator tab system.
2. Withstand duty cycle of ½ second "ON", and 2½ seconds "OFF."
3. Have ac solenoid brake incorporating holding torque of 4.5 to 8.5 pound-inches. This brake to stop the rotor —which is turning at 11,000 rpm—every 3 seconds without overheating.
4. Prevent overriding of tab system by stopping rotor within 40 revolutions at no load.

SOLUTION
by Chicago Pneumatic

All specifications were met by a CP-841J7 Actuator Motor, using the patented CP Low Inertia Rotor. It successfully met the "ON-OFF" duty-cycle requirements with the essential fast braking action needed to prevent overriding.

CP has immediately available hundreds of basic designs and types of aircraft motors and actuators suitable for adaptation to your immediate requirements. In addition, a competent staff of motor specialists will work with you to help solve your motor problem. For full information write *Chicago Pneumatic Tool Company, 8 East 44th Street, New York 17, N. Y.*



CP-841J7 Actuator Motor, shown half size.

Chicago Pneumatic

AVIATION ACCESSORIES • PNEUMATIC TOOLS • ELECTRIC TOOLS • DIESEL ENGINES • ROCK DRILLS • HYDRAULIC TOOLS • VACUUM PUMPS

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DATA PREVIEW

THERMOMETERS—Thermistor thermometers capable of temperature measurements in the range between −328 and 845 deg F are described in bulletin B by **Atkins Technical, Inc., Dept. S/A, 1276 W. Third St., Cleveland 13, Ohio.** It lists ranges for various models of three and four-scale instruments.

Write in No. 499 on Reader Service Card

SYSTEMS DESIGN—Engineering, manufacturing, research, testing and organizational capabilities as well as products and systems are illustrated in a bulletin by **Western Gear Corp., Dept. S/A, P. O. Box 182, Lynwood, Calif.** It is prepared for engineers engaged in the design of major systems in aviation, electrical, electronic, marine and military fields.

Write in No. 500 on Reader Service Card

SERVO MOTORS—Basic models of precision made servo motors, sizes 8 to 29, for scientific, military and industrial applications are described in catalog No. 5000 by **John Oster Mfg. Co., Dept. S/A, 1 Main St., Racine, Wis.** Included are dimensional drawings, physical, electrical and mechanical characteristics.

Write in No. 501 on Reader Service Card

FASTENERS—More than seven thousand items and sizes in stainless steel, such as AN and MS fasteners, cap screws and bolts, nut washers, etc., are among the items listed in a catalog by **Star Stainless Screw Co., Dept. S/A, 699 Union Blvd., Paterson 2, N. J.** It also features rivets, cotter pins, piano hinges, and other products.

Write in No. 502 on Reader Service Card

PRESSURE INDICATOR — Description of method of operation, dimensions, materials of construction, and optional features are contained in bulletin A-109 by **Aircraft Porous Media, Inc., Dept. S/A, 30 Sea Cliff Ave., Glen Cove, N. Y.**

Write in No. 503 on Reader Service Card

SILICONE RUBBER — Silicone rubber specifications are contained in selector chart, CDS-145, prepared by **General Electric Co., Dept. S/A, Waterford, N. Y.** It is designed to assist designers and engineers.

Write in No. 504 on Reader Service Card

BLIND RIVETS — Dimensional drawings for PT and 9SP rivets are dealt with in Form 8-409 prepared by **Huck Mfg. Co., Dept. S/A, 2480 Bellevue Ave., Detroit 7, Mich.** It contains illustrations of driving cycle for each type.

Write in No. 505 on Reader Service Card

more on page 348

Write in No. 256 on Reader Service Card at start of Product Preview Section

CUSHIONING PACK—A cushioning pack for packing all types of items for transit and storage is described in a folder by **Blocksom & Co., Dept. S/A, Michigan City, Ind.** Featured are such products as radar units, missiles, mechanical brain units, and liquid oxygen fuel controls.

Write in No. 506 on Reader Service Card

MERCURY SWITCHES—Catalog 90b describes the standard line of mercury switches issued by **Minneapolis-Honeywell Regulator Co., Micro Switch Div., Dept. S/A, Freeport, Ill.** Included are photographs, dimensions, electrical ratings, drawings, and application and technical data.

Write in No. 507 on Reader Service Card

AIRCRAFT ACCESSORIES—A catalog of valves, strainers, filters, accumulators and other products for aircraft, missile, and industrial applications has been prepared by **Koehler Aircraft Products Co., Dept. S/A, 409 Leo St., Dayton, Ohio.** Valves are divided into five design groups.

Write in No. 508 on Reader Service Card

INSULATION RESINS—A chart listing the uses and comparing the properties of standard electrical insulating Randac epoxy systems has been prepared by **Mitchell Rand Mfg. Corp., Dept. S/A, 51 Murray St., New York 7, N. Y.** The resins are designed for impregnating, potting, casting, sealing, and coating of electrical components.

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MAGNET WIRE—Basic information on original research as well as the engineering data on high temperature ceramic insulated magnet wire for service up to 1000 deg F is the subject of a brochure by **Secon Metals Corp., Dept. S/A, 7 Intervale St., White Plains, N. Y.**

Write in No. 510 on Reader Service Card

SEAT FITTINGS—Descriptions of aircraft seat fittings, seat and cargo tie down track, and a new tool for installation of lockbolts, and other products, are described in a catalog by **Brown-Line Co., Dept. S/A, 111 Main St., El Segundo, Calif.**

Write in No. 511 on Reader Sevice Card

TOGGLE SWITCH—An ultra-small toggle switch for aircraft panels, geophysical equipment, transistorized devices and other areas where space and weight are at a premium is the subject of data sheet 158 by **Minneapolis-Honeywell Regulator Co., Micro Switch Div., Dept. S/A, Freeport, Ill.**

Write in No. 512 on Reader Service Card

more on page 350

MOUNTING SYSTEMS—Space-age capabilities in engineered systems for shock, noise and vibration control is reviewed by **Lord Mfg. Co., Dept. S/A, Erie, Pa.** Bulletin No. 714 covers the capabilities for handling any mounting system.

Write in No. 513 on Reader Service Card

URANIUM & THORIUM FOIL—Uranium and thorium foil and different ways they can be supplied are described in data sheet NU-7 by **M & C Nuclear, Inc., Dept. S/A, P.O. Box 898, Attleboro, Mass.** Fabricating procedures and quality control facilities are discussed.

Write in No. 514 on Reader Service Card

COATED TUBINGS — Physical, electrical data, application information and the main features of coated tubings are contained in a catalog by **Minnesota Mining & Mfg. Co., Dept. S/A, 900 Bush Ave., St. Paul 6, Minn.** A cross-reference chart gives the NEMA temperature rating of each type of tubing.

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RESIN SYSTEMS—Complete data on fast curing, one-part epoxy resin systems in the form of "Scotchply" brand reinforced plastic tape electrical applications has been issued by **Minnesota Mining & Mfg. Co., Dept. S/A, 900 Bush Ave., St. Paul 6, Minn.**

Wrte in No. 516 on Reader Service Card

SEAMLESS TUBING — A technical handbook, A-2, describing seamless aircraft tubing, carbon and alloy steel has been issued by **Copperweld Steel Co., Ohio Seamless Tube Div., Dept. S/A, Shelby, Ohio.** It covers definitions, military and AMS specifications. Charts, tables, and drawings are included.

Write in No. 517 on Reader Service Card

BERYLLIUM OXIDE — Properties, chemical analysis and applications of Beryllium Oxide, a high temperature refractory product is described in a booklet by **Brush Beryllium Co., Dept. S/A, 4301 Perkins Ave., Cleveland 3, Ohio.** Also it offers a bulletin describing the hot hardness properties of four beryllium copper casting alloys.

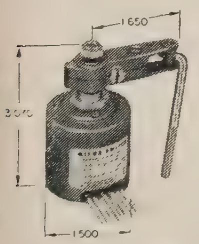
Write in No. 518 on Reader Service Card

SEQUENCE INDICATORS — Panel mounting phase sequence indicators are described in an illustrated catalog sheet by **Opad Electric Co., Dept. S/A, 43 Walker St., New York 13, N. Y.** Bulletin 1551 covers seven standard modes, and includes dimensioned outline drawings of the instruments.

Write in No. 519 on Reader Service Card

WHY SWITCHES GET SHOOK UP

Designing precision switches for aircraft and missiles raises the simultaneous problems of meeting specifications and having the laboratories and test equipment that prove performance. Take vibration, for example. To be valid, a vibration test like the one shown above must simulate the frequency range and intensity of the particular vibrations the switch will encounter. And that is only the beginning for the switch. It must pass other qualifying tests that may include intense heat, subzero cold, extreme pressure, shock, radiation, and other conditions of high-speed, high-altitude flight.



AN "EN" SWITCH

Takes time? Costs money? Of course! But when you weigh the expense and effort devoted to testing against the importance of being sure, you know why these sealed "EN" switches (among others) are shaken up and battered, but good . . . why the name MICRO SWITCH is synonymous with dependability and precision in airborne switches.

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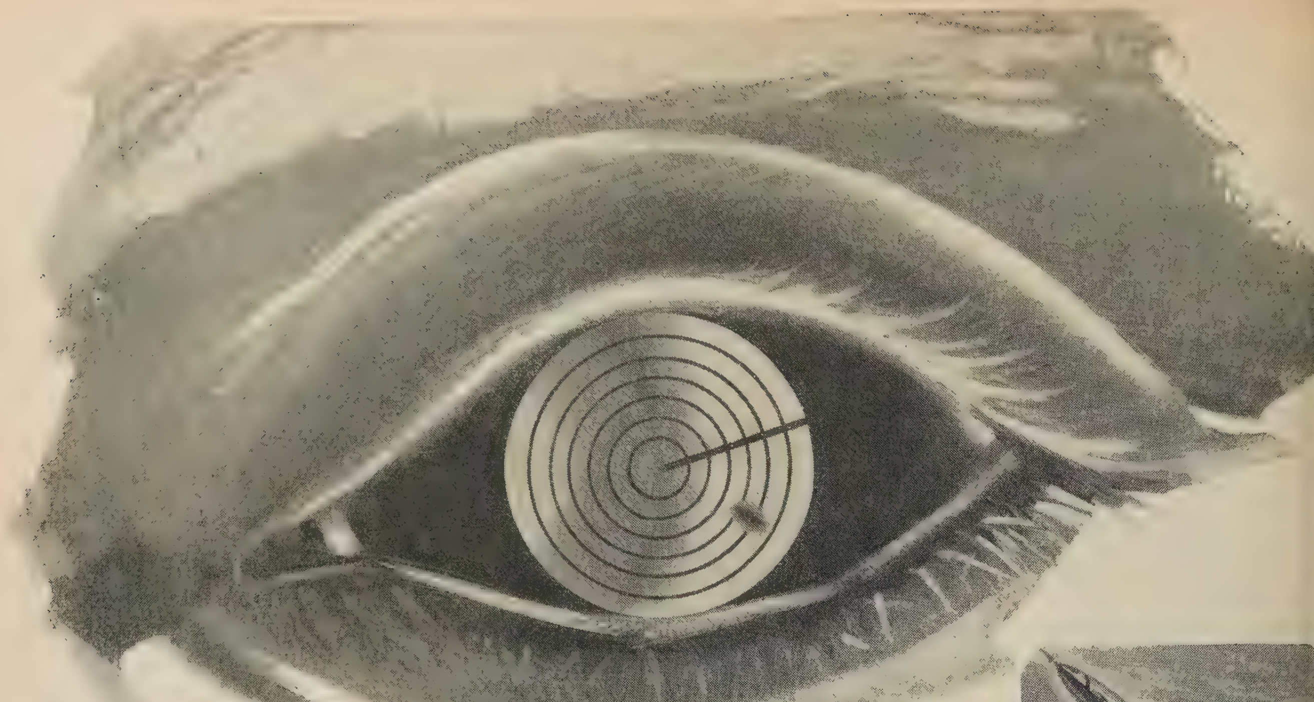
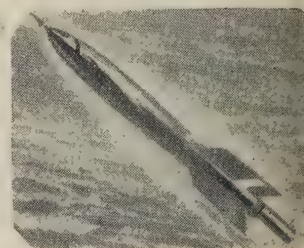
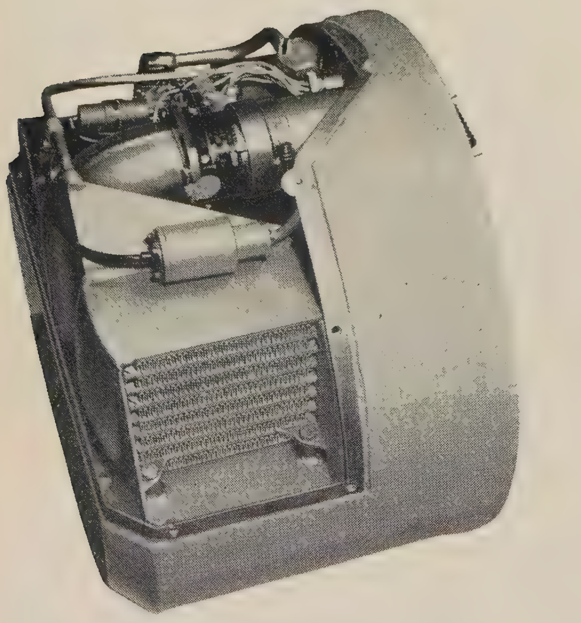




When a PIP becomes a PICTURE *UAP* cools the TV tube!



A new radar tracking system, developed by Sperry Gyroscope, will pick up and track an object at a considerable distance. When the object comes within equipment range, a television camera, developed by Du Mont Laboratories, can pick up the target and show visually its identity.

Cooling and temperature control for the TV Vidicon tube and associated electronic components was assigned to a UAP mechanical refrigeration system. Components are an aluminum plate type condenser and evaporator, semi-hermetically sealed 400 cycle compressor, blower, controls and chassis. The envelope is 14″ dia. x 10″ long, with half the diameter reserved for the tube circuit. Capacity of the 26-pound package is 275 watts at a maximum ambient of 149° F. The UAP system was designed for shipboard application and to meet necessary MIL environmental requirements.

The pip-to-picture story demonstrates but one of UAP's many capabilities in electronic cooling. Other achievements involve liquid cooling systems, expendable refrigerant systems, and gas-to-gas heat exchanger systems. Get complete information on any of these . . . or submit your application problem today for UAP design study!

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NEW YORK..................50 E. 42nd St., New York 17, MU 7-1283
OHIO......................1116 Bolander Ave., Dayton, BA 4-3841
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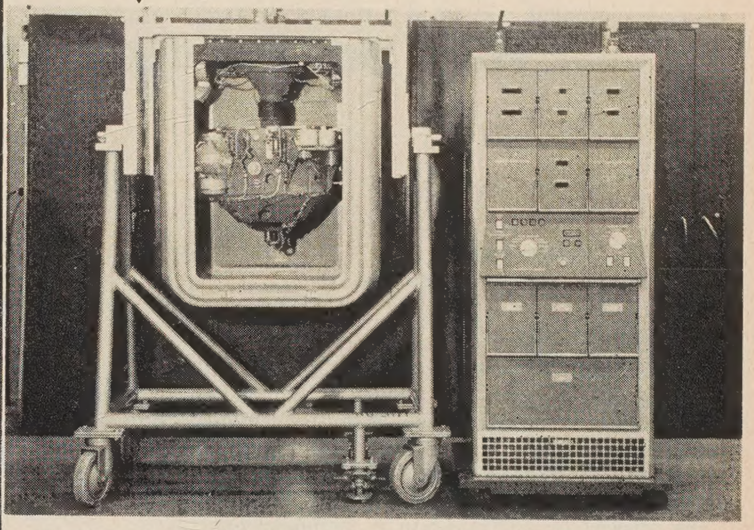
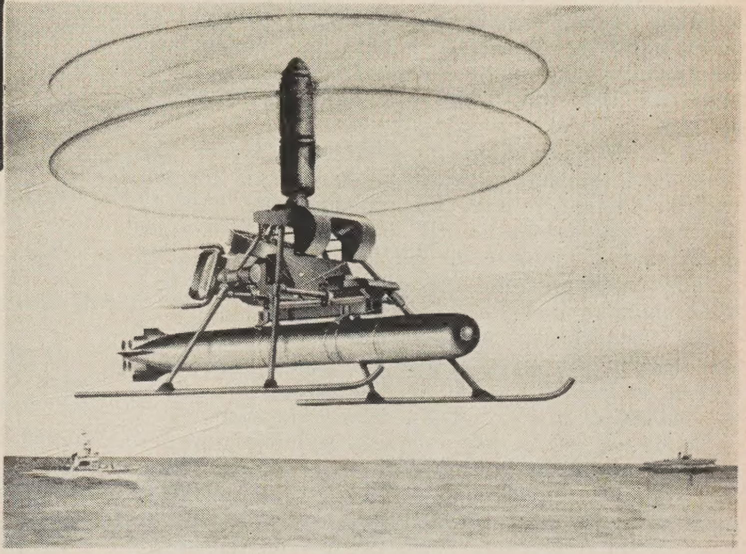
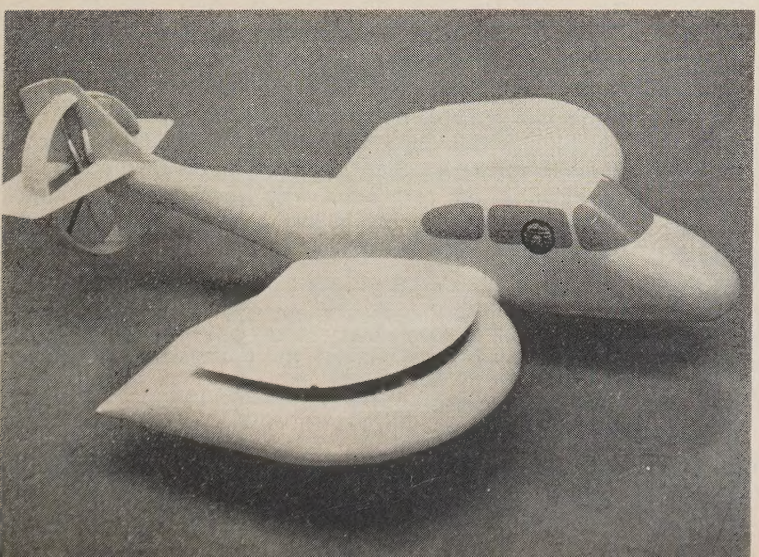
▲ **SOLID PROPELLANT** casing made of new AM-355 stainless is tested for strains in various sections. The new stainless is a precipitation-hardening type developed specially by Allegheny Ludlum Steel to give high strength-weight ratios.

ITS INERTIAL N7A navigation system for the Polaris subs has successfully gone through lab tests, Autonetics reports. In binnacle at left are stabilized platform, precision gyros, and velocity meters. All other electronic equipment is housed in the separate console at right. ▼





▲ **TORPEDO-CARRYING** DSN1 drone copter, under development at Gyrodyne, and destroyers will make up the Navy's Dash anti-sub weapon.



◀ **NEW "OMNIPLANE" VTOL** craft is being ground-tested by Vanguard Air & Marine, of Paoli, Pa. In its final configuration, the plane is to have a ducted prop in each wing, with a flat, plate-type closure on top and a venetian-blind closure below. The tail will feature a shrouded pusher prop.

readers' round table

Why Soviets lead in space race

by **A. E. Hochstein**
Strong Electric Corp., Toledo, Ohio

WHEN THE SHOCK of the first Sputnik was followed by subsequent bigger shocks of bigger Sputniks —and now a successful moon shot—the engineers in missile work felt more frustrated than ever.

Why had the Soviets gained such an important lead in this field in such a relatively short time?

The answer to this question is as unexpected as it is simple. The Russians were bound to surpass the U.S. in the launching of giant-size missiles. It is notable that the practical mind of the American engineer, trying to make the impossible come true, is partly to blame for this.

At the time our missile programs were started, the fuels then available provided limited thrust for the rockets. Obviously, size, total weight, and payload therefore were greatly limited. Payloads had to be used wisely to accommodate all the equipment needed for a sophisticated program. Therefore, all components had to be made as small and light as possible.

The American technology with its boundless enthusiasm rose to the occasion and provided progressively smaller components in an endless stream to satisfy the demand of missile instrumentation engineers.

Should we wonder that reliability suffered from this continual shrinkage in component size? Worse, precision suffered in a measure as the tolerances of these small parts got more difficult to maintain. The direct result of this might have been the infinitesimal errors in guidance that brought us failure where the Reds succeeded.

For isn't an error of 0.001 in. in a part 0.1 in. big only half as good as an error of 0.0001 in. in a part two inches high?

The step from regular to small size was one of manufacturing technique. The next step, from small to miniature, began to demand skills and some research, which became more intense with the leap from miniature to subminiature equipment. When subminiature appeared too big, microminiature parts rapidly became the target of every designer worth his salt. This trend hasn't stopped. Already we hear of molecular modules with a density of some 34 million parts to the cubic foot.

The manner in which our technology solved these problems reflects well on the spirit of investigation of the American engineer.

But it is good to stop here for a moment and consider the spot in which the U.S. is because of this unfortunately one-sided effort.

We have some hundreds of pounds of satellites in space. The Soviets, on the other hand, have a few thousands of pounds of satellites circling the earth.

The Soviet industrial potential in electronic equipment—without in any way underrating it—is years behind its American counterpart. Production is in thousands of pieces, whereas the U.S. turns out millions. Miniaturization is in its first straggling steps; here it is an accomplished fact.

However, the preceding paragraph gives all the answers why the U.S. lags behind the USSR in the field of missiles.

The lack of "small" equipment forced the Soviet scientists and engineers to look for propellants that could carry their bulky and heavy instrumentation into space.

If Soviets had had micromodules . . .

If the Soviet engineer had had micromodule equipment at his disposal their satellite progress might have followed a course more parallel to our own. There would have been no need to put super-Sputniks into orbit.

We should remember that engineers can solve problems in two ways. The problem without technological limits will be solved by going around the difficulties met along the way. The problem with set and rigid limits will be taken as a personal challenge by many scientists and engineers. It will lead to new and sometimes remarkably unorthodox solutions.

We had no super-propellants, so the easiest way out was the micromodule. The easiest way out for the Reds was the super-propellant and the giant missile.

Let us set our own limits with forethought. We shall be able not only to regain lost ground, but surpass all others in the race for space.

Contributions to this department may be on any subject, technical or nontechnical, about which readers would like to air their views. Names and professional affiliations will be withheld on request.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